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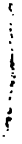

THE

TRUE THEORY OF THE SUN

SHOWING THE COMMON ORIGIN OF THE SOLAR SPOTS AND CORONA,
AND OF ATMOSPHERIC STORMS AND CYCLONES,

WITH

THE NECESSARY FORMULÆ AND TABLES FOR COMPUTING THE
MAXIMUM AND MINIMUM EPOCHS OF SOLAR ACTIVITY,
AND THE PASSAGES IN TIME AND PLACE OF THE
CHIEF DISTURBERS OF THE WEATHER, FROM
THE EQUATOR TO THE POLES IN
BOTH HEMISPHERES

BY

THOMAS BASSNETT

AUTHOR OF "OUTLINES OF A MECHANICAL THEORY OF STORMS."

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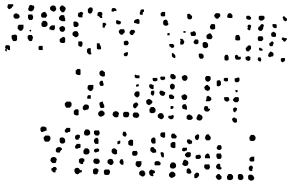

PREFACE.

A NEW work presented to the public is always regarded and treated as a candidate for its favor, and it is expected that the author shall give some account of its object as well as subject, to enable that public to act intelligently in the premises. This is both right and reasonable, and the author feels the more anxious to make himself thoroughly understood, because the THEORY herein presented has a history which the public ought to know. The work is not written for the man of science. It does not soar above the general level of an educated understanding, nor out of the region of experience. Its statements abound in no uncommon technical phrases, but rather aim, by appealing to simple analogies, to invest the subject with a common-sense interest for all who have the good of their fellow-creatures at heart, and for whom nature has some charms.

Furthermore, it may be stated that the reader will find in these pages an uncompromising dissent from the teachings of infidelity, and from agnosticism in every form. It may be accused of a lack of conservatism, if boldness in questioning the dogmas of the schools be deserving of such a charge; but if these dogmas are in any degree contrary to the analogies sanctioned both by Nature and the Word, the author glories in the stigma thereby conveyed, and willingly accepts the taboo placed upon his name.

That we are living in an age of great mental activity is a truism which few will deny; for not only is knowledge increasing, but the desire and facilities for obtaining it are increasing also. The greater educational appliances which we possess, as compared with the recent past,

have broken down the barriers which formerly hedged in the Temple of Knowledge against all but a favored few; so that now there are no difficulties (which cannot be easily surmounted) in the way of any one with the proper faculty, not only becoming familiar with, but proficient in, the most abstruse branches of physical research.

The author is conscious that much has been written on solar physics, and if he merely intended this as a compilation of what has been discovered, he might as well spare himself the labor; for there are many works devoted to that purpose far more complete. But his office is different. It is to *interpret* phenomena and not to state problems. The sun and its surroundings have been treated by astronomers of acknowledged celebrity with a thoroughness due to the importance of the subject which, so far as the amateur of physical science is concerned, meets all requirements. In Prof. Young's "Sun," and in Mr. Proctor's earlier work on the same subject, we find pretty much all which can be gleaned from recent writers. They give us in eloquent words all that is known of our great luminary, and this is all that the man of leisure usually requires. To these publications the author would respectfully refer every one who may be induced to purchase the present volume; but should the reader, after perusing those works, rise from the repast dissatisfied with his fare, we may assure him that he is not alone; for, although the *menu* is sumptuous in the extreme, there is left a craving for plainer and more substantial food. In other words, we feel like the Roman Seneca when he wrote the words, "*Felix qui potuit rerum cognoscere causas.*" Candor, however, merits praise, and when the writers we have mentioned confess that the sun and its surroundings constitute the great mystery of physics, we concede that virtue to them; but at the same time would mildly suggest to the reader, that this confession is the strongest argument for the publication of the present work, whose credentials are an undeniable ability to divest that sub-

ject of its mystery, by referring all solar phenomena to one common mechanical principle, applicable to the Sun and all other stars, as well as the earth and all the other celestial bodies of our system. In the wondrous mechanism of nature, it may be that man shall never comprehend the intricate working of wheel within wheel, nor give a true solution of the problem; but it is something to gain a level ledge of rock on the mountain side whereon to rest for a while, until we can, by surveying the steeps we have climbed, decide how far our progress hasbeen in the right direction, or how far we must retrace our steps in order to take a fresh departure. And this we claim for the theory herein expounded. It *may* be true in *all* its details. It may be true in *some* of its details. Then again the truth may be widely different, and yet the theory cannot be charged with coming into collision with any *sound* principle of science. So far it has the advantage over other theories, and so far it is entitled to respectful examination.

But this is not the only claim it has on public favor. Quite early in the century the author was led to speculate on the hidden causes which were competent to change, in a few hours, the balmy quiet of a summer eve into a night black with tempest, and roaring with the sweep of the besom of destruction. The result of those speculalations was published in 1854 under the title of "Outlines of a Mechanical Theory of Storms." The present work may be considered a supplement to that, by giving a more explicit account of many physical questions which were then only briefly indicated. That theory, after thirty more years of observation, is proved to be a true theory, and it is of some importance that the history of its origin and development should be preserved, as well as of the adverse influences which have cheated the world out of the benefits which might have resulted, had not science emphatically condemned it. While this volume, then, is ostensibly devoted to solar physics, its most prac-

tically valuable feature is the proof, which the elucidation of solar phenomena affords, of the truth of that "Mechanical Theory of Storms," by the application of the same identical principles which conduct us to the true causes of atmospheric disturbances. It has therefore been deemed necessary to present a brief synopsis of this history in the introductory chapter, and to insert in the Appendix copies of such papers as are needed as witnesses, but which would not, on a first perusal, interest the general reader.

In those early years the author had a few staunch friends who had faith in his professions (and whose encouragement will ever be remembered) when all the world was against him. For those friends, whose faces he has not for a long time seen, and may never behold again, and also for those known only by name, whose correspondence cheered him in the days when the *res angusta domi* had a hard reality, he has appended a souvenir, regardless of the misinterpretations and aspersions it may call forth from those who have committed themselves to a senseless opposition of what they cannot, or will not understand.

Grave questions like those which constitute the subject of these pages are inevitably stated and discussed in earnest terms, and where a great variety of phenomena are traceable to the same causes, repetitions are more or less unavoidable; but when the importance of those questions and their novelty and antagonism to recognized theories are considered, the reader will find some advantage in such repetitions, which place the same ideas in different lights, and thus enable him the more fully to comprehend the particular points deemed fundamental. Let him also reflect on the immense gain to our knowledge of the weather, and on the benefits which would accrue to all, if this theory were proved true; and he may then feel a responsibility resting upon himself, to advocate its claims to a just and impartial examination by a properly accredited and competent tribunal.

The author might add a few words bespeaking from all a spirit of amicable forbearance, for labors hastened by a long sickness which warned him that what he wished to do, must be done quickly. This might, by some, be regarded as a valid excuse for blemishes, which no doubt may be detected in his work. But he is too conscious of the opposition it will meet with, to expect from science a more lenient verdict than it has already given, and he will ask no quarter at its hands. No longer troubled by hope deferred, he can calmly look on, and despise the petty shafts to which he is invulnerable, feeling confident that what he has herein advanced is TRUTH, and, if truth, no words can be too emphatic in protesting against that intolerant spirit of caste, which, by its opposition made it impossible to obtain a hearing for a theory which gives such promise of stripping meteorological phenomena of all mystery; for meteorology is, of all the sciences, the most practically important to mankind.

In speaking thus of Science the reader will, therefore, understand the author to speak of those who *claim* to represent it, and not to that humble spirit of devotion which seeks to bring the things which are seen within the limits of human comprehension, as the first great step to a right understanding of the things which are not seen.

To speak in language less pointed would be moral cowardice. Better accept the consequences and have the approval of a few kindred spirits, than drift with the current which is sweeping a deluded majority to inevitable oblivion.

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INTRODUCTION.

THE author of these pages is anxious to disabuse the reader's mind of any prejudices he may entertain against a theory unrecognized by the Professors of Science, unless a virtual condemnation thirty years ago by the A. A. A. S., at its Washington Session, may be called recognition. In order to do this, it is needful to refer to its inception and history from the beginning, which will enable each one, for himself, to form a correct estimate of its subject, of its object, and of its truth.

If we look back on the path of human progress, we learn how slow has been the general advance, especially until the last two or three centuries of the Christian Era, and it is only by considering all the influences pressing down the human intellect in those early times that we can comprehend the abject slavery under which it was held by the favored few, to whom circumstances of birth, ancestry, and political or hierarchical position, rendered it possible to acquire a knowledge of natural phenomena, and of the causes to which they owed their origin. Now the same influences are still felt, although in a very much diminished degree. It is natural and even necessary that it should be so. The masses have been, in all ages, fully occupied with the wants of the body. Ignorance on all other subjects was the rule until all outside questions were regarded as incomprehensible mysteries; so that the privileged custodiers of the key of knowledge were looked upon as superior beings, and their teachings or dogmas, no matter how absurd, were regarded implicitly as the truth. Since the revival of learning, the human intellect has rebelled against such teachings, and claimed

the privilege of investigating phenomena and speculating on their causes. Yet so dependent is the majority on others, that should some daring spirit question conclusions generally accepted, few would be found independent enough to examine for themselves whether that distrust was well founded or not.

This is sure to be the fate of every truth enunciated by those who have worked their own way, independent of the teaching of the schools.

The author of the present theory was at an early age much given to speculate on the causes of things, and conspiring circumstances directed his first steps to nature in acquiring that knowledge. Subsequently, he found many of his speculations were admitted facts taught in every institution of learning of good repute, and therefore sought eagerly for such knowledge where it was to be found. Still, after all, there was an unsatisfied craving for more solid nutriment, and as his experience of the hurricane had impressed him often with its awful sublimity, it became a favorite study to refer to some intelligible cause, the great contrast between a day of storm and blackness, and the serenity of clear weather with scarcely a breath of wind to float a thread of gossamer; and this, too, with only an interval of a few hours between.

The result of long study and observation was the conviction that, the moon was at least a very potent factor in disturbing the weather in accordance with ancient and popular traditions; but that it could not be dependent on her phases, nor on her distance from the earth, as these particulars would be similar for every longitude and latitude simultaneously, and *that* was not consonant with observations made in widely separated regions. Nay! even within the trifling distance of 4° or 5° of latitude, the very contrast spoken of above would obtain; so that if the moon were, either in whole or in part, the cause of such differences, then some explanation was re-

quired to distribute this influence in some ever-changing order, so that every part of the world would get its share of wind and rain and electric disturbance equally by turns; subject of course to the influence of the local features of contiguity to mountains, deserts, seas, woods, plains, and the general set of the aërial currents.

How early the crowning idea crossed his mind he cannot now exactly recall; but in 1844 he had so far advanced in developing it, that he memorialized Congress on the subject. That memorial was presented by Hon. Sydney Breese, Senator from Illinois, and was referred to the Committee on Agriculture, as a decent way of disposing of a question distasteful to the science of that time.

As this introduction is mainly to present the evidence, not only of the nature and reality of a great discovery, but also of facts and dates necessary for the thorough understanding of the question, the first paragraph of that memorial is herewith inserted.

"OTTAWA, ILLINOIS, June 1st, 1844.

"The undersigned citizens of La Salle County, in the State of Illinois, on their oath, present; That, whereas they have been acquainted with Mr. Thomas Bassnett, of Ottawa, for many years, during which time he has repeatedly professed to have made certain important discoveries in relation to the weather, even claiming the discovery of a mode of calculating the passage of storms, etc., for any particular place and for any future time, which professions they have heretofore been disposed, with many others, to regard as extravagant and baseless; justice, however, now requires them to confess, that when their particular attention was directed to his predictions, they could no longer doubt but that they were founded on sound principles.

"In order, however, to enable others to judge for themselves, we subjoin a brief narrative of facts, etc."

Very soon after or during the erection of the buildings

for the Smithsonian Institution, the author communicated with Prof. Henry, and a long correspondence ensued, resulting, after a personal interview at Chicago, in the publication of an outline of the general theory at his request. This outline was consigned into the printers' hands in December, 1853, and published as 'Outlines of a Mechanical Theory of Storms,'—the storm feature being the only question treated of in much detail. Copies were sent to many of the prominent savants of this country and of Europe.

"At the annual meeting of the American Association for the Advancement of Science, held in Washington, May, 1854, a paper was read before the Meteorological Section —Major Emory in the chair—embracing the numerical details of Bassnett's Theory of Storms, when, on motion of Prof. Peirce, of Cambridge, a committee was appointed to investigate it, with instructions to report to the Association at its next annual meeting, and the following gentlemen were accordingly appointed:

"Prof. Joseph Henry,	Washington, D. C.
" A. D. Bache,	" "
Lieut. M. F. Maury,	" "
Prof. B. Peirce,	Cambridge, Mass.
" A. Guyot,	" "
" Jos. Lovering,	" "
Dr. T. R. Beck,	Albany, N. Y.
W. C. Redfield Esq.,	New York.
Dr. Robert Hare,	Philadelphia, Pa.
Prof. J. F. Frazer,	" "
" Lewis R. Gibbes,	Charleston, S. C.
" John Le Conte,	Athens, Ga. "
Dr. E. H. Barton,	New Orleans, La.

"At a meeting of this committee, May 4th, 1854, in Washington, it was resolved that the theory should be tested by its power in predicting the weather in different latitudes, and that Mr. Bassnett be requested to prepare such

particulars for Cambridge, Mass, Washington, D. C., and Charleston, S. C., to be distributed to suitable observers, who should compare the weather with the predictions, and report to the chairman of the Committee."

We give the following extract from the pamphlet published by the Committee: "The theory contends that the existence of an universal imponderable medium possessing inertia and great specific caloric, and subject to all the laws of matter and motion (gravitation alone excepted), is proved by the determination of the motions of a series of eddies or vortices in the medium, arising from the fact that the centre of the earth is not coincident with the axis of the ethereal vortex surrounding it. That the axis of the vortex is inclined to the earth's axis, and consequently these vortices follow the moon in right ascension, and describe orbits whose apogees are variously situated in longitude, and are caused to circulate over the earth's surface between the *average* limits of 10° and 80° in both hemispheres; exempting both the poles and the equator from the disastrous presence of the hurricane. The theory further contends, that all storms and atmospheric commotions are *primarily* due to the passages of these vortices, and that not a single storm has ever occurred, of which sufficient details were recorded to enable him to interpret its aspects that contradicted the theory" (see the Pamphlet published by the Committee, and "Bassnett's Mechanical Theory of Storms," by D. Appleton & Co., New York).

The reader need not be reminded that the value and range of many useful discoveries are apt to be exaggerated by the one who makes them, without any disposition to misrepresent; and so it was in the present case, when an additional ten years of experience had taught the author that the disturbances in our atmosphere were susceptible of many modifications from causes, either independent of the moon, or so remotely connected as to make it, at that present, impossible to follow up the clue, if so connected,

for want of the necessary data. So conscious was the author of the vast extent of territory covered by the problem he had, unaided, undertaken to solve, that in all his communications he merely represented himself as a pioneer who had by chance, as it were, stumbled upon an unknown shore, whose latitude and longitude he had pretty correctly ascertained, but whose interior he could *then* only describe from distant views obtained from the summits of its hills. Now, as the cause is *electrical*, or due to derangements in the equilibrium of the ether immediately contiguous to the mechanical disturbance, and as dry atmosphere is a poor conductor of electricity, or of that motion of restoration by which the disturbed fluid is brought back to a state of equilibrium, it follows that the disturbance must be commensurate with the moisture or watery vapor in the local atmosphere, and when that is wanting, no visible disturbance is observed. A visible disturbance is the formation of clouds from condensation, and that condensation may be rapid and excessive, in which a furious cyclone may be originated; but absolutely dry atmosphere is altogether incompatible with the production of the hurricane, or the tornado, and, therefore, until we know something more than we now do of the laws which connect the great equatorial currents coming up at uncertain times loaded with moisture at a high temperature, with the revolution of the moon in her orbit, or with the special effects due to the passages of the vortices in particular latitudes, we can only determine the probable times when storms may occur, and, therefore, the demand made by the committee above named was obviously intended to give the theory its quietus. Accordingly, in preparing the paper demanded of him, he distinctly disavowed the power of predicting storms, which the committee had chosen to attach to his theory. This disclaimer constitutes the first paragraph of the paper he prepared for it, and is inserted here in full, as follows:

"Before entering on the predictions, I must remind the

committee that the action of these vortices depends much on the state of the atmosphere, that is, on the waves of high and low barometer; and particularly on those great currents which alternately bring up a great body of vapor-loaded air from the south, and the dry, cold streams from the poles—the first presenting a medium far more permeable and more easily acted on by the medium to which the vortex belongs than the last. And the laws which regulate these alternations are yet too involved to connect in time and place with the motions of the vortices, which obey a definite and geometrical law. On this account it is impossible to say *when a great storm will occur*. The theory can only, at present, point out when such is probable, and indicate, generally, the direction and changes of the wind, which of itself is of vast utility to the navigator. The rest must be left to his own observation of the aspects of the sky, the state of the barometer, and the general character of the weather. Sometimes the weather will be beautifully fine for many days, during which several vortices will pass over. At such times the wind will be generally dry and northerly; the cirrus, at the passage, will not exhibit those curved threads, or branching plumes, or long pinnate shafts, which indicate the active motion of the ethereal medium through the air; but, on the contrary, it will appear like a thin stratum of fibres without a directive force, or like a portion of cotton batting spread out to the last degree of continuity. There is also an appearance, in such weather, when a vortex is passing, which indicates a quiet passage—a hazy sky without cloud; but in which streaks and small lucid waves can be detected by close observation. These must be the highest of all visible clouds, if clouds they be, for they are more like waves of light than the reflection from the comparatively dense mass of the flimsiest cirrus cloud. When an approaching vortex appears, however, as a thick bank of a misty or watery appearance; when the small, low cumuli pass rapidly towards it, and seem surrounded by a pho-

tosphere or halo for 2° or 3°; and when the sky at sunset looks of a lurid red, or in the daytime tinged with prismatic haze, great electrical excitement may be expected; and where this is, heavy squalls of wind are sure to follow. These remarks might be extended indefinitely, and are scarcely called for. Many close observers of the weather have an intuitive feeling, not easy to explain, of what looks bad in the heavens; and there are very few who do not pretend to this species of knowledge.

"It would seem scarcely necessary to suggest to men of science that a pretension to have reduced all the anomalous complexities of meteorology to such definite laws as to make a foreknowledge of the weather absolutely attainable, would of itself be a broad imposture. Those not versed in the difficulties of the subject expect to be told when it will rain in a given locality, forgetting that, under the equator, the heaviest and steadiest rains often occur in a perfect calm, and there these vortices never reach. A shower is not a storm, although rain usually (in middle latitudes) is only produced by the passage of a vortex. The navigator is more interested in the violence and direction of the wind, and it is to this point the theory more especially applies. But even granting a partial failure of its power of predicting in such cases, let it be remembered that the world has not arrived at such knowledge; that, at the present day large sums are spent by governments and individuals to get some clue to the obscure laws which govern the weather; and that this theory only professes to calculate the orbits of certain disturbing causes which are continually circulating around our globe, and at least to predict their visibility in time and place. I say, in view of these facts the verification of such calculations ought alone to be sufficient with the scientific, without exacting the evidence of its present practical utility. The motions of these vortices from south to north and from north to south, are according to astronomical laws. They are somewhat like comets,

whose dimensions are so large and whose perihelion passage is so close to the observer that he can get no chance of estimating the position of the centre; and, consequently, the determination of the elements of their orbits, and of the inequalities which affect them, is rendered extremely difficult. This difficulty is also vastly increased by there being twelve passages in four weeks, not one of which is labeled or characterized by any especial distinction. Yet for all this, I assure the committee that these elements are determined, all in accordance with the principles of a theory, which, thus being proved true, is respectfully commended to their consideration with reference to its bearings on the other great questions of physical science."

At the following meeting of the A. A. A. S., at Providence, R. I., in 1855, the report of the committee on Mr. Bassnett's Theory of Storms was presented by Prof. Henry, as follows:

"Prof. Henry stated that Mr. Bassnett's theory had been tested by the committee by observing the weather and noting its correspondence or want of correspondence with his (Mr. Bassnett's) predictions. The predictions of the theory *were verified during the first ten days tolerably well;* but were found worthless during the remaining time of observation, or for nearly two months." (See Proceedings of the A. A. A. S., page 293, at the Providence meeting.) Feeling the injustice of such a report, the author mailed to each of the committee named a circular, dated August 1st, 1855, protesting, "that one of the useful discoveries of the age is retarded in its progress to practical perfection by men to whom circumstances have assigned the position of leaders in promoting discovery and diffusing knowledge among men." But the protest was sent to many other members of the A. A. A. S., detailing, somewhat minutely, "the principal characteristics of his 'Mechanical Theory of Storms,' based on the assumption of an universal plenum of a highly elastic fluid in motion,

and that this fluid (called electric ethereal or magnetic) was necessarily imponderable, but possessed inertia; and that its specific heat or motion excelled that of all other matter. When the details of the theory were presented to the Association there was one serious error of fact vitiating the numerical elements. It was supposed that there were only six vortices, one central and five secondary (or lateral). Since then, a seventh has been satisfactorily determined, so close to the central as to have been confounded with it; and hence discrepant values were deduced for the other elements. This last was named the Bi-central from its position. Below I give my latest values of these elements."

As the values then approved (referred to in this extract) were obtained from observations made in one latitude, and as the author subsequently changed his latitude by 11°, he has been able since to polish those elements by that change of latitude and lapse of time. These will be found in the paper, inserted elsewhere, read in 1881 by the author at the Cincinnati meeting of the A. A. A. S.

This represents the present state of the theory here given to complete the record, and to afford to those inclined to prove its worth the means of so doing, by giving them the numerical values of the improved elements and the formulæ and tables necessary for the computation of these vortex passages to which our weather changes are mainly due, with some examples to facilitate the application of the formulæ. His labor on this question will not therefore be lost if some one with health and will should regard them with sufficient confidence to put the theory to the test of observation.

For himself he cannot longer devote his time to such pursuits; but in the following pages, wherein the theory is more fully developed in its application to solar and planetary phenomena, the reader will find such evidence of its truth as will convince him that, in its application to lunar and terrestrial phenomena, it is true also.

While apologizing to the general reader for the apparent incongruity between these details and the ostensible subject of this volume, the author requests him to consider the practical value of confirming a theory of our storm agents, to whose destructive fury all are more or less exposed; and this can best be done by the successful application of the same principles to problems which the scientific world has virtually acknowledged to be inexplicable. If we can give a rational solution of the nature of the solar spots, and of their periodicity, of their greater frequency in certain solar latitudes, and of the mechanical cause to which they owe their origin, as well as of the cause of all other solar phenomena, the protuberances and the tremendous velocity of their formation, the corona and its rapid changes, the coronal rifts and rays and their different aspects at different times, the zodiacal light, and that almost instantaneous sympathy observed between the earth and sun on special occasions, besides that more gentle influence which emanates from the sun and affects the meteorology of our globe in periodical variations. And last of all, as respects the sun, if we can give a rational account of the origin of the solar fires, and show the groundless fears of those who are prematurely mourning over its blackened ruins, and of all the members of the solar system. If we can demonstrate that the same principle is the cause of all great changes in the earth and planets, and pre-eminently so in the case of all our atmospheric commotions, we shall then feel exonerated for considering our present labors as a mere supplement to our "Mechanical Theory of Storms," in which the reader will find all these explanations *outlined* in 1854.

If this be not an idle boast, the successful application of the same identical principles which strip solar phenomena of much of their mystery, to the clearing up of the fog which hangs over the meteorology of the earth, will surely render superfluous the above apology, as it

will constitute the strongest argument of all for the existence of an ethereal medium with the particular attributes assigned to it; proving that all nature is unanimous in confirming a truth, and that sun and planets and satellites are bound together by material ties, as well as by dynamical laws, and acknowledge the family relation in every feature of their being.

When a man *thinks* he has discovered a great truth of value to his fellows, it is expected of him to impart the evidence on which it rests to the world at large, in order that its claims may be tested; and although his announcement may be treated as idle words, he is not justified in taking offence, when satisfied that his discovery is founded on facts, and his theory based on solid principles. The very feature which, of all others, is most opposed to its reception is the extreme difficulty of detecting the facts from the very indefinite phenomena to be observed; which difficulty can only be diminished by familiarity with it, which again can only be acquired by persevering observations, backed by implicit faith in the reasoning on which the theory is built.

To determine the elements of one of our atmospheric vortices requires many observations of latitude and longitude at its meridian passages. The passage observed may be to the north or to the south with its boundary lines beyond the observer's horizon. It may be the same as previously observed, or it may be the passage of another vortex moving in the opposite direction. The passage may be made at a time of continuous cloudiness or in comparatively clear weather (which is more favorable for the observation); but the difficulty is confessedly great. It is this very difficulty which enhances the value of what has been discovered; for if it reveals the true origin of our storms and cyclones, and thus directs our investigations on the right course, we ought to make good use of the clue, obtained under circumstances which may never again occur. And this must be the author's justification

for putting on record the following paper, which gives a synopsis of that portion of his theory which relates to our own world, while he utterly disclaims all thought or desire for any benefit arising from love of notoriety, of fame, or of lucre. These he emphatically repudiates as the tinsel baubles which have ceased to charm.

PAPER READ BEFORE THE PHYSICAL SECTION OF THE A. A. A. S., AUGUST 20TH, 1881, AT CINCINNATI, OHIO.

Numerical elements of the orbits of the seven electrical vortices to whose motions atmospheric storms are principally due, with the processes by which they have been derived, and examples given of the application of the formulæ, by which their position on the surface of the earth can be computed for any given time.

The fundamental postulate of this theory is, that infinite space is pervaded by a subtle imponderable medium which conveys to us the light of the stars and is in all respects material, having inertia and specific heat, but differing from ponderable matter in its extreme tenuity. That the derangements of its equilibrium cause electric manifestations, and, therefore, it may be called the electric or ethereal fluid.

Assuming that at the beginning the solar system was in a nebulous state, rotating around a common centre as disseminated particles, its rotation was similar to the rotation of the medium in the manner of a vortex composed of a series of vortices, the largest of which occupied the axis and centre of gravity of the whole nebula.

Confining ourselves to the vortex of the earth, and bearing in mind that the matter involved in it was divided between the earth and moon, and, therefore, on the principle of preserving a mechanical balance, it is plain the centre of the earth could not occupy the centre of the vortex; but that it would be displaced by the moon in proportion to the relative masses of the two bodies. Thus the earth would be an obstruction to the circular current and there would arise lateral vortices or eddies as in any other fluid obstructed in its flow.

The number of these vortices is seven; whose axes are assumed to be all parallel and inclined at this time 22° 22′ to the earth's equator—the nodes being in 364° 20′ and 184° 20′ of longitude. By the action of these vortices the electrical equilibrium of the atmosphere in proximity to their transit latitude is disturbed, which causes an influx of the colder outside medium,—whose specific heat must far transcend that of all other fluids,—thus causing a great fall of temperature as one prominent result of the disturbance which at the first produces a contrary effect. The great question to be determined is, do these vortices exist? In answer to this, I appeal to phenomena of daily occurrence of the most palpable character, giving due weight to the frequency of their occurrence in harmony with the astronomical principles on which the whole question is based.

It would occupy too much time to allude here to the successive steps which led to the discovery of the true signification of those familiar facts which unmistakably connect our most violent atmospheric disturbances with the moon. And when it is announced that there is a periodicity in the time of the passages of these vortices (I do not say in the amount of the disturbances), whose irregularities obey and follow the irregularities of the moon's motions, and which, therefore, can be calculated from the data afforded by the Nautical Almanac, I find myself in the position of a man whose sanity is viewed with suspicion by his fellows, who take credit to themselves for great forbearance in withholding the candid expression of their real opinions. This conviction has been forced upon me—the result of long experience.

In 1844 a memorial was addressed to Congress setting forth this discovery of the orderly motions of a series of electrical vortices in our atmosphere to which our storms are principally due. Several years later a similar announcement was made to the government of Great Britain. In 1852 and 1853 the question was brought before

the Smithsonian Institution, and, after much correspondence, the opinion was given that the alleged discovery "had not even any *a priori* probability of being true in its favor," and therefore assistance was declined. In 1854 a paper was read before this association convened at Washington, and a committee was appointed to examine into the subject; but this committee exacted conditions which rendered an adverse report a foregone conclusion. So much so that I had no alternative but to protest against its injustice, which protest was published and distributed among the members of this association in 1856.

On the occasion of the total solar eclipse in 1869, I ventured again to call attention to the subject, connected as it was with the solar corona.

In 1877 and 1878, at Nashville and St. Louis, attempts were made to remind the association of the importance of these alleged discoveries, while last year a communication was sent to the Royal Astronomical Society in London, to be presented at the discretion of the secretary, which, of course, was not presented.

In my last effort to obtain a hearing, I received the unusual acknowledgment of the reception of my comunication by the War Department at Washington, and the courteous assurance that it should be carefully studied by the Chief Signal Officer. But in about a month from that time I received notice that the subject *had been* examined, and it failed to convince that officer that its statements ought to be accepted as well established facts in meteorology.

(The correspondence will be found in the Appendix, Note B).

We are all aware that there is, in many widely separated countries, a lingering faith in the moon's influence over the weather; but, mistaking the *modus agendi*, the key to a reconciliation of facts and theory was not found during the long ages that are past, by the philosophers

of antiquity. Neither has modern science done anything towards accomplishing it; but, rather, on the other hand, has labored to dispel such faith as an illusion, the offspring of ignorance and superstition, calculated to embarrass research, and, therefore, a belief in such an influence is generally regarded as a stigma on a man's scientific reputation, or as a sign of intellectual weakness in any one who has the hardihood to avow it. Nevertheless, if truth is ultimately to prevail, we shall have to recognize its claims, and adapt our future researches in meteorology to its indications.

Here I beg to say one word on a question which will naturally suggest itself. If the preceding synopsis is entitled to respectful examination and comparison with facts, the phenomena on which the system is based must be more or less palpable, more or less periodical, and more or less linked to the moon's numerical elements. And a greater difficulty presents itself in the question: how could such correspondences have escaped detection to this late day?

Science, backed by the leading governments, commenced attacking this question many years ago, and has failed to detect them, and, therefore, the inference is obvious that such correspondences cannot exist. This presents a very formidable difficulty to contend against, and it is to meet it that this paper has been written.

I have in the present paper unreservedly given the elements of the problem, the results of over forty years observations, and to obtain which it has been necessary to wade through an ocean of fruitless computations. The numerical values thus derived are no doubt but approximations, yet I believe close approximations, and, when it is considered that, at the beginning, every quantity was an unknown quantity, and the difficulties which meteorological investigations labored under were, forty years ago, vastly greater than at present, the time and labor will have been well expended, if these elements

now enable us to identify the several vortices by computing the latitude of their passages over any given meridian, and for any given time. And this is the problem before us.

These elements, and the formulæ for using them herewith exhibited, will enable any one versed in the use of logarithms, in ten minutes to determine the position of any one of the seven vortices. And by selecting those passing near his own latitude he will be able to determine their existence, and to compare, every three or four days, the appearance of the sky and the changes of the weather with the latitude of passage resulting from his computations.

Any one, devoting himself to these researches, will be soon fascinated by the study of the sky necessarily involved in the general problem, and while he will find its aspects of very great variety, he will soon begin to associate with a particular vortex some peculiarities not possessed by others. All may pass without violence, and even, in very dry and dense conditions of the atmosphere, it may be sometimes difficult to establish the passages; yet generally the observation can be reconciled with the calculation, while at other times the correspondence is wonderfully exact.

It must be borne in mind, however, that at present it is beyond our power unconditionally to foretell what will be the character of the weather at any calculated passage; yet the calculation will enable us to interpret more correctly the visible and instrumental indications at the time of passage, and thus be of practical value to the navigator, whose perceptive faculties are ever on the watch for signs of a brewing storm. Again, in times of long continued low barometer, the vortices being seven in number and usually limited to a range of only sixty degrees of latitude, and each having to make two passages over any latitude within its range (except at its extreme limits) a descending passage when passing from north to south, and an

ascending passage when passing from south to north, in one sidereal period of the moon—or in less than twenty-eight days—it might, of course happen that, as the vortices are only on the average two days apart, there would be no interval of clear sky separating the passages; and in proportion as this state of things obtained, the difficulty of detecting any such arrangement of disturbed and cloudy belts would be exaggerated; and in this and kindred anomalies we find sufficient reason for their non-discovery, while, at the same time, finding it impossible to doubt their existence.

In reality the disturbances are more than two days apart, for the reason that in every latitude reached by them there are certain vortices (different for different latitudes) which pass the given meridian in the same latitudes on the same days, one ascending and another descending, thus complicating the question.

There is also a more marked display at the passage of a descending vortex than of an ascending vortex, perhaps owing to the angle which the axis of the vortex makes with the surface of our atmosphere causing a deflection of the ethereal current to the south, and thus begetting a southerly wind at the beginning of a storm, and a hazy sky gradually thickening into stratus by the ascension of such a current under the line of passage, caused by the mechanical effect produced on the upper layers of air which are impelled southward by the influx of the outside ether; and also from the fact that a descending vortex is usually followed by a northerly current when its action has been violent; thus naturally ending a disturbance which an ascending vortex began with a southerly wind. This is the usual routine of a storm in the northern hemisphere.

But to enumerate details of this character is not the object of this paper, and this remark must suffice, that all these elements and the practical deductions made from comparing the results with observation, pertain chiefly to

north latitude 30° and longitude five hours and a half west of Greenwich, where these statements can be best verified.

A sojourn of a year in more northern latitudes (which failing health would not permit) would perhaps have rendered some slight changes necessary; for if one element is defective all the rest will have to be modified.

That the elements are not absolutely perfect is due solely to the ill-defined nature of the phenomena, rendering it impossible to tell, in any single case, the central line of passage within thirty or forty miles.

I shall, therefore, say nothing here of the great influence which the barometric and hygrometric conditions of the local atmosphere exert in determining the extent of a disturbance at the time of any particular passage, which influence, so far as is now known, is apparently independent of the astronomical part of the problem.

When these views are accepted by the scientific, and observers are multiplied, we may possibly connect the fluctuations of the barometer with the positions of the vortices, and derive from past records great assistance in forecasting the general character of the weather.

Now it is easy to show, by continued fractions, that the ratio between the moon's sidereal period and the tropical year will bring the same passages around to the same days in each month—within a fraction of a day—every eight years, when the reversal of the node is taken into account; and as the revolution of the moon's perigee is completed in nine years, it brings the lunar parallax to nearly the same value in eight years, and THAT parallax is what mainly governs the radius vector of each vortex in its own little orbit described on the surface of the earth.

Three such periods of eight years, erroneously divided into two periods of twelve years, have been adopted by Glaisher and others as a probable weather cycle, and if, as is very probable, the solar spot period should be found greater than 11.11 years, it would conform to that larger

cycle of 56 years which has been proposed as a weather cycle. Fifty-six years, or 8 × 7 years = 20,454 days. Six semi-revolutions of moon's nodes = 20,380 days. If the solar spot period conforms, we have five periods of 11.2 years (the length first given by Wolf), equal to 20,454, and approximately for the lunar perigee; for 6 × 3,232.57 days = 19,400 days.

But it should be borne in mind that a weather cycle for one latitude will not answer for another latitude for special dates; for while the general character of the season may correspond over wide tracts of country in one hemisphere, the very causes which produced it where summer reigned would not be effective in the same sense in the opposite hemisphere; and for special dates, while a passage is made in a particular latitude, and bad weather is thereby caused, 5° or 6° to the north or south there is no vortex near and no disturbance of the weather.

But such cases of commensurability constitute another very potent element of change, partially harmonizing with the moon's motions, thus rendering past records of the weather usefully available for comparison in the future.

I consider the foregoing remarks as a necessary introduction to a right understanding of the technical details of the problem, a familiarity with which will show to every one disposed to be convinced by probable evidence, not only that these vortices exist as a part of the atmospheric machinery of the world, and that their number has been correctly determined, but that they have only escaped recognition by observers of the weather for want of a rational theory connecting them with the motions of the moon.

There will be no rigid conformity in the effects of a vortex passage to any procrustean rules whatever; but the effect will be produced during the twenty-four hours *following* the passage, and it must be remembered that the action of the sun is an important adjunct in producing it.

The accompanying diagram represents the relative po-

sitions of the earth and moon, when the moon is in the extreme southern part of her orbit.

EE' being the equator, PP' the poles, LL' the parallels 15° and 75° (assumed for the sake of argument as the limiting parallels north and south), and QQ' the ecliptic. We will assume, also, that the plane of the ecliptic is coincident with the plane of the terra-lunar vortex c ☾, and, therefore, VV' will be the poles of the vortex. Now, taking the mass of the earth and moon as 85 to 1, the centre of gravity of the two bodies will be at C, and through this point the axis of the vortex parallel to VV' passes, around which axis the rotation of the surrounding medium is performed.

This axis then might, *a priori*, be taken as the central or principal vortex; but long continued observations have established the fact that there is no vortex in that position; but instead there are two vortices, one on each side of that position, and called the central and bi-central. The other vortices are due to the obstruction of the circular current caused by the earth thus pushed out from the centre by the moon; and are in the nature of lateral eddies.

Now in this position of the two bodies, the lowest limit of latitude reached by the central vortex is 15°, and in half a lunation* afterward the vortex will reach its highest limit, say on latitude 75°, as the other vortices have mean radii not much different (the true values and their position angles being in the general table), what is here said of this vortex will apply, *cæteris paribus*, to all. Now if we draw the lines VL, VL', they will represent the natural cosines of the vortex latitude, calling QQ' the equatorial plane of the vortex, whose pole is VV'', and the arc $Q'L'$ will be the *vortex* latitude, and as the pole of the earth and the pole of the vortex are here represented in the same plane, the arc $Q'L'$ – the arc EQ' will give us the

* Half a sidereal period is here to be understood.

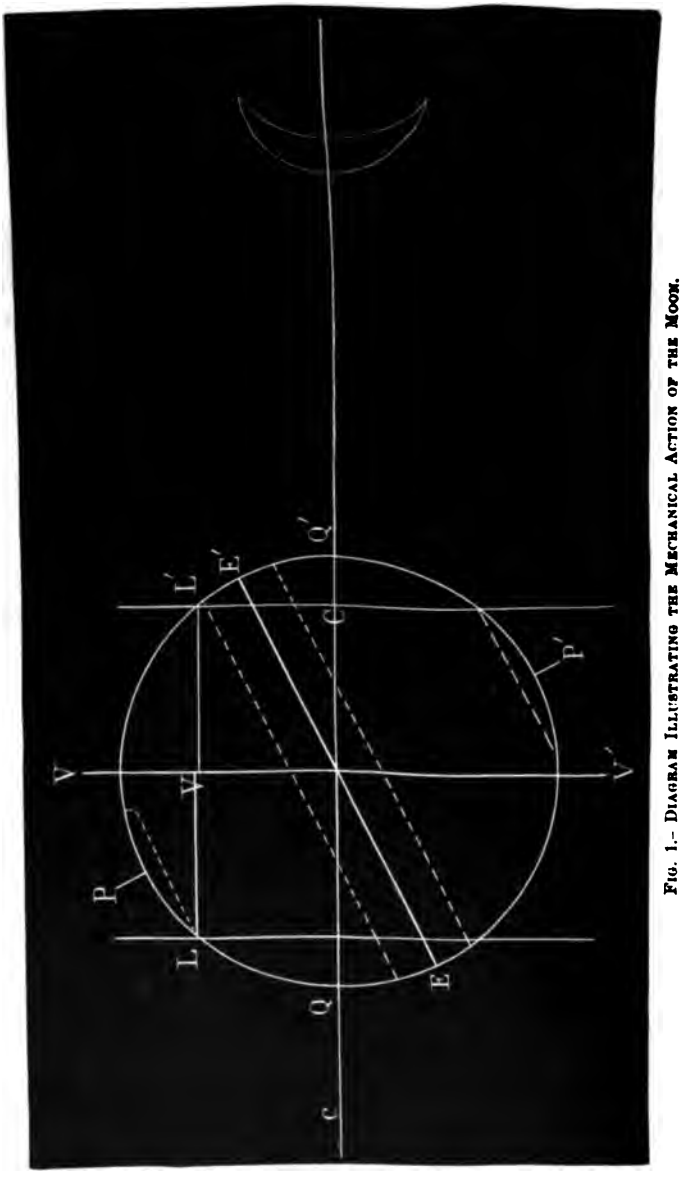

FIG. 1.—DIAGRAM ILLUSTRATING THE MECHANICAL ACTION OF THE MOON.

geographical latitude of that particular vortex on the surface of the earth, on a meridian determined by the longitude of the moon at the given date.

So also, when the moon and vortex are at their northern limit the latitude will be equal to the arc QL + the arc EQ. In other positions the obliquity of the vortex plane with respect to the earth's equator renders it necessary to compute the spherical triangles, all right-angled, and therefore three simple equations will give us the latitude required. If the vortex is descending—or passing from north to south—we refer the triangle to the node in 184°.20′, and if ascending—or passing from south to north—we refer the triangle to the node in 364°.20′, or in 4°20′. I now give in tabular form the constant elements derived from long observation and persevering comparisons.

TABLE OF ELEMENTS.

Vortex Name.	Descending and Ascending Symbols.	Product of Vortex Mean Radius and Moon's Mean Parallax.	Vortex Longitude or Position Angle from Moon.	Constant Correction for time of coming to Meridian.	Inclination of Vortex Plane and Longitude of Nodes.
		K	P	F	
				h. m.	In. 22°.22′ = C.
Central.	☉ ☉	2410	20°	1.34	☋ = 184° 20′.
2d Inner.	☽1 ☽1	2450	80°	5.32	☊ = 364° 20′.
2d Outer.	☽2 ☽2	2330	140°	9.40	d = displacement in lat. =
Middle.	☽m ☽m	2220	200°	13.48	.036 cos.(☾ − ☉ + 90°).
1st Outer.	☽0 ☽0	2225	250°	17.14	D = displacement in lon-
1st Inner.	☽1 ☽1	2420	290°	20.00	gitude = 2° sin (☾ − ☉).
Bi-central.	☽B ☽B	2300	350°	24.00	See Tables in Appendix.

On the 26th of May, 1881, three months before this meeting, I sent a paper to the secretary of this Associa-

tion (who certified to its reception) as an illustration of the theory, containing the calculations of the passages of two vortices over the meridian of Cincinnati, only one of which is here given. The whole process of calculation herewith presented is that of the first outer vortex ascending (⟋10⟍). The calculation shows that the passage will be made over this meridian at midnight of the 19th of August in lat. 37° 12′, about 2° south of Cincinnati, and according to the theory ought to show *evidence* of its passage on the 20th as a bank of clouds in the south and clearer north.*

* The following is a brief record of the weather, and several members of the Association were invited to remark the correspondence of fact and figures after the reading of the paper, which was read on the same day, Saturday, August 20th, 1881, about 5 P.M., after the record was made :

"August 20, 6 A.M., bands of thick cirrus stretching from south to north, sky hazy generally, wind light, N. E.

"10 A.M.—Blue sky visible in north.

"NOON.—A dense bank in south as a well-defined arch, much clearer north."

There was truly nothing striking to an ordinary observer, but the evidence was as calculated; and such evidence ought, at least, to enlist the curiosity of any man of intelligence who can divest himself of scholastic prejudices. To make the theory practically useful requires the aid of ten thousand observers scattered over the world, savage and civilized. One great question to decide is : whether great storms do not occur when there is a conjunction of two vortices and the atmospheric conditions are favorable ? In middle latitudes a conjunction can only happen between an ascending and descending vortex. In the tropics it might occur when two contiguous vortices happened to be near their turning point, and remained near the same latitude two or three days together. To determine this question requires a nicer adjustment of the elements than they, perhaps, can boast. On the night of August 27th, 1881 (a week after the reading of the above paper), one of the most fearful hurricanes on record swept over the Island of Tybee, and did great damage in Savannah, Ga. Now if we take the elements from the table for the central descending ⟍9⟋ and the second outer ascending ⟋20⟍, and the moon's upper transit, longitude, and parallax from the Nautical Almanac, we shall find that the ⟍9⟋ crossed the meridian of Savannah at 5 P.M. of August 27th in latitude 31° 3′, and that the ⟋20⟍ crossed the same meridian a little before midnight of the 27th in latitude 31° 12′. A very close conjunction of two vortices in latitude and longitude. That meeting will be long remembered. The latitude of Savannah is 32° 8′ north.

When a vortex is ascending (or passing from south to north) its initial letters are placed in an inverted ⋁, thus ⋀, and when it is descending, the symbols are placed erect ⋁ (as in the table). The central vortex is the one first supposed to represent the axis of the vortex, but subsequently it was discovered there was no vortex there. Yet it is still so named, as it is not very distant, and the seventh (the last discovered) being also near, is named the bi-central. The axis of the vortex is between these two. The other vortices are lateral, and named as outer or inner, according to their proximity to the axis, and in their order, in coming to the meridian, beginning at the axis. Their longitudes are reckoned on the vortex plane in order of right ascension, taking the longitude of the moon on that plane as zero. Thus the longitude of the central vortex = ☌ long. + 25°, and so for each, always adding the vortex longitude from the table to that of the moon's ecliptic longitude for the given time.

In the following diagram (Fig. 2) the node of the vortex plane on the equator QQ' is at C, and the triangles

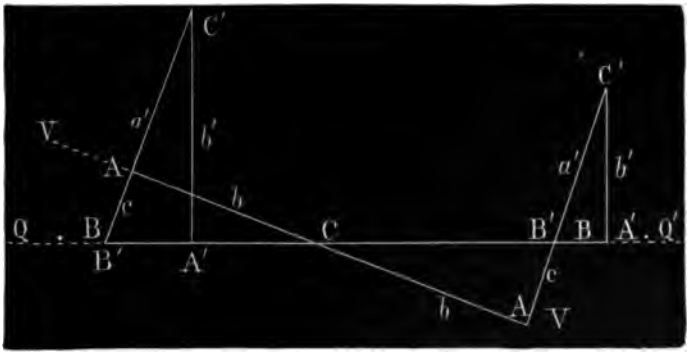

Fig. 2.—A Vortex Passage Referred to the Descending Node.

represent right-angled spherical triangles applicable to all cases whose sides and angles are designated in the example given below. That example will answer as well

for a descending passage as for an ascending one by merely changing the node by 180°.

In this diagram, considering the triangles as spherical triangles, C will indicate the descending node and $V\,V'$ the plane of the vortex, $Q\,Q'$ being the earth's equator. But the angle C is the inclination or obliquity of the vortex and is assumed as constant. If the vortex longitude be less than that of the node, the relation of the known and unknown quantities will be explained by the left hand triangles. If the contrary, the right hand triangles will best exhibit it, remembering that the accented letters belong to triangles whose plane of reference is the earth's equator. The unaccented triangles are estimated on the vortex plane.

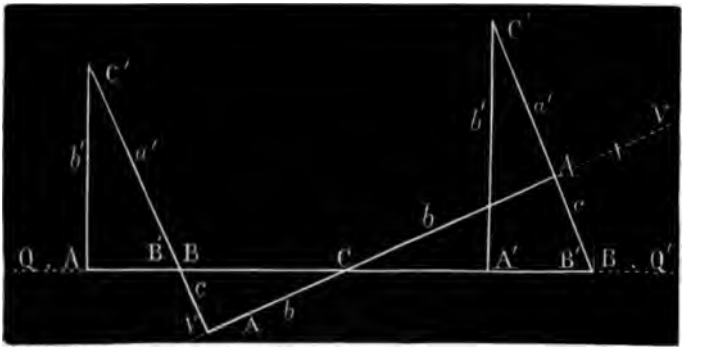

FIG. 3.—A VORTEX PASSAGE REFERRED TO THE ASCENDING NODE.

At the ascending node the relation is different, as the diagram shows.

MERIDIAN PASSAGE OF ♌ IN W. LONGITUDE 85°.

GREENWICH TIME OF PASSAGE.			TABULAR CORRECTIONS.	
	h.	m.		
M August 18,	19	51	☾ longitude,	97°
F " "	+ 17	24	☉ "	147
D " "	− 1	22	☾ − ☉	310
W " "	+ 5	40	$D = 2'\sin(☾ - ☉)$.	
G " 19,	17	33	$d = .036\cos.(☾ - ☉ + 90°)$.	

LOCAL TIME OF PASSAGE 11.53, OR MIDNIGHT OF AUGUST 19.

Value of b.			Value of a'.	
☾ longitude at Passage,	96° 47′		K =	2225
D =	− 1 33		X =	3256
P =	+ 250 00		Q =	.68335
V =	345 14		d =	− .01500
☊ =	364 20		N =	.66835
V − ☊ = b =	19 6		a' =	48° 3′

TO FIND LATITUDE OF PASSAGE ON MERIDIAN OF CINCINNATI.

Tang.	C =	22° 22′	Logarithm	9.61435
Sin.	b =	19 6	"	9.51483
Tang.	c =	7 40	"	9.12518
Cot.	b =	19 6	"	0.46057
Sin.	c =	7 40	"	9.12518
Cot.	B =	68 56	"	9.58575
Sin.	B' =	68 56	"	9.96995
Sin.	$a' - c$ =	40 23	"	9.81150
Sin.	b' =	37 12	"	9.78145

p, d and D are explained and tabulated in the Appendix.

EXPLANATION OF NOTATION AND SYMBOLS USED.

M = The time of moon's upper transit at Greenwich.
F = The longitude of the vortex converted into time.
p = The time by which a vortex precedes or falls behind its normal place. See Table in Appendix.
W = The time due to geographical longitude of the place for which the calculation is made.
G = The Greenwich time of passage of the particular vortex over the meridian of the place.

☾ = Moon's true longitude at the time G.
D = A displacement in longitude with argument, sine (☾ − ☉)
P = Position angle or vortex longitude, the moon the origin.
V = Longitude of the vortex on the ecliptic.
☊ ♑ = Longitude of the nearest node.

K = The product of mean radius by moon's mean parallax.

Q = The quotient of $\frac{K}{X}$; radius equal 1.
d = Correction for radius, argument cosine ($\mathfrak{C} - \odot + 90°$).
N = Natural cosine of vortex latitude (see diagram).
a' = Arc AC' corresponding to vortex latitude.

In the three equations following the addition of the two first logarithms of each equation gives the answer in logarithms.

The question is to find the side of the right angled spherical triangle which represents the geographical latitude of the passage = b', to find which we have given C, b and a'.

The whole calculation, to determine the position of any vortex in either hemisphere for any past or coming time, need not occupy more than ten minutes if the Nautical Almanac is available; for it is to be observed that, although the elements may be imperfect, the error between the latitude of the actual passage and the computed passage can never be much, as the moon keeps all the vortices in fixed positions, and *her* motions regulate *their* motions each lunation.

We will now show how we can obtain the correct value of the radii and position angles of the several vortices, after having ascertained their number and the inclination of the plane in which they move.

In determining the number, we have to assume an approximate value of the mean radius of a vortex, and of the inclination to the ecliptic of that plane. The mass of the moon gives us the first, and the ecliptic, as the average inclination of the plane of the lunar orbit to the earth's equator, gives us the second.

By continued observations, we find that in the same latitude, the same vortex passes from north to south and from south to north, when the moon is in the same longitude approximately. In time, then, we are able to say there are only a certain number of passages in one lunation, and when we have arrived at this knowledge, we be-

gin to tabulate, and set down the descending passages of the same vortex, noting the observed, or rather estimated, latitude of these passages, and selecting, if possible, the passage made to the north of the observer in one lunation (or, if it so happens, one north and one south), and in the next lunation one made to the south ; and thus alternately for many years. The same is to be done for the ascending passages of the same vortex alternately north and south, on the opposite page of the record.

Now the average latitude will in a measure be free from errors in the estimation, and the errors dependent on the possible influence of the angle between the sun and the moon will be eliminated by the multitude of passages in every possible position of these bodies. Setting down these latitudes in one column, and in another column the moon's longitude at each passage, we then take the averages. In like manner, in another column we note the lunar parallax at the time of each passage and take the average. Now, treating these averages as the true figures corresponding to two passages as if actually observed, will give us a very close approximation to the radius of the vortex ; and, so far as our inquiries are limited to the radius and position angles, we may combine all the ascending passages with all the descending passages, and the two sets of averages will have more than double the weight of one set ; for then the radius at the descending passage is equal to the radius at the ascending passage, and, consequently, the arcs of longitude between the two nodes are equal.

To obtain the position angle of the vortex, we have nothing more to do than to take the difference between the moon's average longitude, for the set of descending passages and the actual longitude of the vortex as given by the computation. For instance, the longitude of the vortex must be either between the ascending and descending or between the descending and ascending nodes. Suppose the last. Then as we have the average longi-

tudes of the moon for both sets of passages, we know the interval between them: but this interval will be precisely the interval between the longitudes of the vortex in the two sets of passages; and we need not compute the arcs b_1 and b_2, for these two arcs added to the interval will be exactly 180°.

Now, suppose the interval between the moon's average longitudes at the ascending and descending passages be 100°, then the arcs b_1 and b_2 are 80°, or 40° each. Suppose, again, the moon's longitude corresponding to the descending passage be 330°, then $180° + 40° + 360° - 330° = 250°$ for the *position angle* or longitude of that vortex. At the ascending passage the moon's longitude would be 70° (*i. e.*, $100° - 30° = 70°$) and $180° - 70° + 140°$ would give the same *position angle*, or $P = 250°$. For ascertaining the value of corrections more elaborate methods have been found necessary.

I have thus tried to condense the results of over forty years of such labor, involving of necessity the sacrifice of those objects esteemed by men generally. Latterly, I have sacrificed health also, and this is one reason why I wish to resign a task too great for a single individual not blessed with youth and health. That some one better able than myself may be inspired to investigate whether these things are so or not, is now my earnest desire; for I testify that this key will be found to fit the locks of many of nature's secrets when handled aright.*

In all other branches of science there is but a very small percentage of the population which feels much interest in their development; but in meteorology, every man, woman, and child, consciously or unconsciously,

* Three years ago (1880) a blue book was presented by the Queen to the British Parliament showing the disasters at sea for the previous seven years to be 1,965 vessels of 729,194 tons and 10,827 lives. Would it not be better to tolerate strange doctrines than to refuse them a hearing, when even a little truth might help to mitigate such evils?

takes some note of the weather as affecting health, pleasure, business, or daily bread.

In conclusion, let me appeal to the past history of science; for I will not refrain from claiming for these discoveries of mine a place as high as any ever vouchsafed to man, because I may be charged with inordinate vanity by those who cannot understand me. In the past, great truths have been discovered, have been ignored by those to whom the key of knowledge was intrusted, and their authors have perhaps during their whole life been tabooed as dangerous enemies of established systems. It rests with this Association to decide whether history is again to repeat itself.

THOMAS BASSNETT.

THE SUN.

CHAPTER I.

THE ETHEREAL MEDIUM.

FROM the insight the reader has already obtained from our theory of the cause which constitutes the great weather disturber of our globe, he will understand the important part the ethereal medium is called upon to play in solar as well as in terrestrial physics. As all nature constitutes one grand whole made after the same pattern, we shall do well to use all *legitimate* analogies derived from our experience of what we can see and handle here, in our endeavors to refer solar phenomena to the same mechanical principles. For what is the electrical force but a mechanical force? We only differ from others in going a little further back by attributing all electrical effects to ultimate mechanical causes. Electricity is but the evidence of the existence of that subtle fluid which must from its elasticity fill all space; for it is the derangement of its equilibrium, whether by the vibratory motion of ponderable atoms, by the displacement of atoms *inter se* as in chemical action, by friction, or by any other forms of motion, which calls forth its mechanical energy in electricity, magnetism, the aurora, the lightning, the earthquake, the tornado, the zodiacal light, the solar spots, the solar prominences, and the solar corona. It is by the undulations of that medium that we receive the light and heat of the sun—directly or indirectly. It is by the same undulations the stars convey to us, not

only their composition and condition, but also, by their variability, the extent of their rule and the relative magnitude of their surrounding planets.

We cannot lay too much emphasis on the controlling influence which the great ethereal ocean exerts over ponderable matter. Nay! it is far more than a controlling influence. It is the very life of the visible universe, and it is the sheerest folly and puerility to stand aloof in an assumed attitude of superior wisdom (as some do) and question, if not deny altogether, the existence of what is absolutely necessary to the right understanding of the most familiar of nature's laws.

Who can question the infinity of space? To deny it is an absurdity. Who can question the undulatory theory of light? Would not a denial of this also be attributed to ignorance? Who can question the reliability of the result obtained by the measured velocity of light—allowing perhaps a margin of the $\frac{1}{1000}$ part of the whole? On such a simple foundation we can build a mighty structure. Space is infinite. It is filled with a subtle, elastic medium to its farthest verge, seeing that this medium obeys no law of gravitation. It is also in motion in mighty currents, straight, curved and vorticose. In the stellar systems its motions correspond with the motions of the ponderable bodies in those systems. It must be, even supposing that it is not the *primum mobile*, but a recipient of motion imparted by contact, *i.e.*, by friction from such ponderable bodies. Both geology and astronomy—the earth and the heavens—open a grand vista into the past, by which we are assured that our system has been long in existence, and comparatively unchanged; so that there must necessarily have resulted, in the lapse of ages, an equality in the amount and direction of that motion, however long it might have taken to produce it. A more philosophic view, however, would be to consider the great beginning in the case of the sun (and of all other suns by parity of reasoning) to be the aggregation of planetary matter in-

volved in some great ethereal eddy, in which the solar nebula of La Place attained its ultimate dimensions, and after the lapse of other ages separated by cooling and condensation into cloudlets, which became the centres of inferior eddies, and thus settled into their present planetary forms. By such a natural process, indorsed by the behavior of air and water in motion—as is familiar to every one—the two great elements—the ponderable and the imponderable—entered into a life-long partnership, to elaborate the various worlds which recognize the suns as the rulers they are required to obey, in accordance with creative will.

While astronomy only recognizes the great law of gravitation as the governing principle in all celestial motions, analogy plainly teaches us that, if there be (as our reasoning powers incline us to believe) an illimitable reservoir of matter in motion, that this great ocean of imponderable fluid has its currents on which are drifting the millions of suns with their retinue of planets, comets, and meteors—like rafts of floating débris on the bosom of a mighty river in time of flood—which have been collected in its great whirls during previous ages as a natural consequence of differences in specific inertia between ponderable and imponderable matter. If gravitation alone be the power to which all celestial motions are due, we ought to find a certain degree of correspondence between the observed motions of the stars and the forces which produce them. But the spectroscope tells of motions far exceeding the velocity of our quickest moving planets when nestled close to the great centre of attraction, and this not in one case only, but in many; so that, without we resort to dark aggregations of matter whose masses exceed our sun many hundred times, we cannot attribute such motions to the force of gravitation; for if we resort to an aggregate composition of the attractive influence of innumerable stars, concentrated on one particular star whose motions are found greater than usual, the very number of surrounding

centres insures such an equality of direction in their influence as to neutralize each others' effects, and, therefore, we are driven to refer those motions to a primitive impulse in the way suggested, an impulse (no matter how derived) which is, and has been, shared with the mass of fluid medium surrounding the stars from the beginning.

If there be no ethereal medium, and the law of attraction is exerting a force across interstellar space utterly void of all that we can call matter, then what is to prevent a gradual but general closing up of the stellar ranks, and the final collection of all the stars into one mighty globe? In such a case there is only one way by which a chaotic catastrophe can be averted. The stars must be infinite in number, and so distributed in position and endowed with motion, both in degree and direction, as will render collisions only occasionally possible. The analogies which nature presents are adverse to both these suppositions: but if we admit what necessity imperatively demands, it is as repugnant to reason to assume that an infinite space is a barren void, as that space is not infinite. But if space be only another name for an infinite ocean of imponderable matter, that matter must be in motion, seeing that the whole visible creation is in motion, and, therefore, constitutes an infinite reservoir of *kinetic energy*, compared with which the attraction of all the ponderable matter in the universe is as a single drop of water to the great Pacific Ocean. The stars may, and undoubtedly do, exert a feeble attraction on each other; but their majestic sweep through the heavens, as measured by their proper motion, is much more due to the irresistible currents of the ether which are flowing on undiminished from everlasting to everlasting.

Among other wonderful results of spectroscopic analysis, the motion of the stars in the line of sight is not the least, if reliable; but are they reliable? A few years ago it was announced that Sirius was rapidly increasing its distance from our sun at the rate of 50 or 60 miles

per second. Subsequently, it was announced that this velocity was diminishing, and now we are told that the recess has changed into an approach. Now as the light of Sirius exceeds that of our own sun, as 200 to 1, it is not unreasonable to suppose that his mass at least exceeds our sun 200 to 1 also, and, if so, we have that vast mass whirled around in an orbit so contracted as to require a central force, competent to change his motion from recess to approach at the rate ostensibly observed, *a hundred thousand times greater than our sun.*

Such an inference justifies the suspicion that such deductions may not be reliable. Neither are they necessary. When a star is approaching with a sufficient velocity to cause a displacement of the lines of the spectrum, that displacement shows a change in the wave-lengths of those particular lines, and when the displacement is on the other side of the normal position, the star is supposed to be receding—the velocity being measured by the amount of the displacement. This is perfectly analogous to the locomotive bell changing its key when two trains pass at great velocities. While approaching, the sound-wave is shortened, but lengthened when receding. Now suppose the bell to be stationary, and a forty mile an hour wind blowing, at first toward the moving train, and after it has passed, from the train. The effect would be the same in changing the sound. Why, then, may not the same effect be produced on the light of a star by intervening ethereal currents, and thus account for sudden changes in the wave-lengths of the spectrum lines, without resorting to the stoppage of a star in its headlong course, in order to reverse its motion? But it will be said that, in a group like the seven principal stars of Ursa Major, if this were the true cause all the seven stars should show the same direction of motion, whereas, Alpha is moving in a diametrically opposite direction. The objection is not serious, as these stars are separated by wide intervals, and it must be remembered that the

wave-length of a ray of light from Sirius or Arcturus is measured by the light which enters the spectroscope, and not by that which first started from the star. It may be, and no doubt is, the case, that there is a general average wave-length from all parts of the sky; but it is probably equally true, that different results will be obtained from the same stars, with the same instruments, at different times.

This question is closely connected with discrepancies in the value of the constant of aberration. In 1854 the author held the same opinion as now, that the difference in the constants derived from the eclipses of Jupiter's satellites and Polaris, was due to the different density of the ether along the equatorial plane of the solar vortex and in the direction of the pole, and to the necessity of discriminating between the observations of Polaris made in summer time and those made in winter; but no notice was taken of the article. (See "Outlines," page 181.) But great stress was laid by others on the impossibility of gravitation being at all connected with the interference of the opposing waves of light, in consequence of the necessary tangential force it would give rise to, seeing that light takes eight minutes in coming from the sun to the earth. But the fact that such a ray reaches the earth in a curve which makes up for the time of transmission, and lands the ray in lines parallel to the radius vector of the orbit, was entirely overlooked.

It may be thought, perhaps, that we are too diffuse on the question of the existence of the ethereal medium; but it is the foundation on which we intend to build our whole system of solar physics, as we have done already in the meteorological department of terrestrial physics, and we shall now proceed to develop it, ignoring the questions which reason can never answer.

We know that there are two kinds of matter, the ponderable and imponderable—"a natural body and a spiritual body"—if science will tolerate a quotation from

the Law and from the Testimony, which the writer is conscious is very problematical. It is true that some names of note in the ranks of science have the courage to avow their belief in Holy Writ; but that belief is too often warped to suit the character of the new era, whilst the mere tyros who constitute the rank and file are to the manor born, and regard opinions which tend to exhibit creation in all its varied aspects as one harmonious whole, as the intellectual débris of a superannuated school, fit only to be swept remorselessly away by the increase of knowledge by which so many are turned unto fables. Truly! it is a delusion to believe that the God of science is the God of the Bible.

Limiting ourselves to what is knowable, therefore, we regard it as worse than useless to speculate on the genesis of matter, or on what constitutes the difference in its ultimate atoms by which such an endless variety of combination is produced as nature exhibits. Neither does it profit to speculate on the nature of force. Our experience renders the fact familiar to us, that the momentum of matter—the product of mass or inertia by motion or relative velocity—measures a force, and if there be forces like the vital force and the will, whose manifestations cannot be traced to some point of contact between ponderable and imponderable matter, it may be only owing to our inability to state the problem from our comparative ignorance of the nature of that very subtle medium which we call ether. That it is matter and possesses inertia we may safely consider indisputable. That it may have its temperature raised or lowered by contact with ponderable matter, whether solid, liquid or gaseous, is also indisputable; for the curve line of perpetual snow in different latitudes on our globe establishes this, so far as our imperfect data can determine it, and hence as heat is but atomic motion, it must have specific heat.

That it is not ponderable is proved by the fact that it becomes more dense or intense as we ascend above the

surface of the earth; so much so, that we can scarcely move at an elevation of 10,000 feet above the sea level without causing a palpable manifestation of its presence. But if it were ponderable, lighter even than the lightest gases, its greatest density would be at the sea level: for if we had an atmosphere of hydrogen superadded to our present atmosphere, that latter atmosphere would not interfere with the gradually increasing density of the layers of the first as they descended to the sea level. We may talk about a vacuum or a plenum, but we know there can be no such things. Even supposing we could exhaust the receiver of an air pump of its oxygen and nitrogen, we could not pump out the ether which permeates ponderous matter as the air permeates the thickest clouds; and as for a plenum, analogy tells us that all matter is instinct with motion everywhere, far as the telescope can carry us, therefore infinite space is a conditional plenum, or plenum of matter *in motion*, or elastic, and therefore compressible into a smaller space, and if compressible its equilibrium can be deranged by force. Thus, taking analogy and common reason to guide us, we arrive at the great truth: that the solar system is but a part of a grand complex whole—the conception and creation of one master mind—arranged according to some fundamental plan with infinite variations in its details. We have, then, a system composed of one central sun, the source of light and heat and living energies, which it dispenses to a number of dependent worlds, our earth among the rest. These worlds are in motion, regulated by a law which, while guaranteeing a general stability, necessarily introduces apparent deviations from its strict working. The law of their motion, then, becomes the law of motion of the ethereal medium of the space in which these motions are observed. In other words, it is fair to presume that the motion of the medium is the same as that of the planets at the same distances from the centre of the solar vortex. Does this motion correspond to the dynamical principle,

that the absolute velocities of bodies moving around a common centre must be equal at all distances from that centre? (see "Outlines of a Mechanical Theory of Storms"). If the distance of a planet be double that of another, on this principle the absolute velocity in its orbit should be equal to that of the other, although its period would be twice as long, because the circumferences of circles are as their radii. But the laws of Kepler give a different ratio for the absolute velocities of the planets; for in this case these velocities would be inversely as the square roots of 2 to 1 instead of being equal. If we designate the distances of two planets by D and d, their respective velocities are *inversely* as $\sqrt{D}$ to $\sqrt{d}$. The ether being independent of Kepler's law would therefore move faster than the planets at the same distance from the sun, which acting perpetually in the same direction, would be a propelling power which must, by continual action, add to the planets' tangential velocity, and increase their distance from the sun. Now as no such increase has ever been detected, we are driven by our theory to seek the evident harmony existing between the medium and the planets in some other feature, and need not go far to discover it. If we resort to an increase in density of this ethereal medium as the distances from the sun increase, we soon discover that, provided we assign a ratio of increase equal to the square roots of the distances from the sun, the dynamical law, above cited, will harmonize with Kepler's third law of the motions of the planets (see "Outlines," page 163).

Now if the ether of space be not absolutely imponderable there can be no gravitating force between the particles of any matter, however dense, for it is the universality of this very medium which links the created universe into one compact whole, whether finite or infinite; and if ponderable it cannot be universal.

The author is well aware of the assumed air of *amiable* contempt which has been exhibited on his behalf by kind-

hearted physicists for the *aberrations of an ill-balanced mind*, for which he here returns thanks; but he cannot see any argument in such wasted sympathy, for suppose the velocity of light and heat be insufficient to evade the conclusions of La Place (see Mec. Celeste, liv. xvi.) that the velocity of the gravitating force is, at least, 50 millions of times greater than the velocity of light. If we compare the velocity of sound in a comparatively dense fluid like air, with the measured velocity of light in the ethereal medium, the last exceeds the first about a million times. Now, if there be three great elements in nature, instead of two, two imponderable and one ponderable, and that the tenuity of that fluid—whose waves travel a million times faster than the waves of sound—be surpassed by the far greater tenuity of another more ethereal fluid, whose waves travel 50 millions times faster than the waves of light, we have an agent competent to explain the force of gravitation, and meet every requirement. And who shall limit the resources of Omnipotence? We cannot escape the conclusion that there is a medium, through whose vibrations the light of the stars comes to us with a velocity of 186,000 miles in a second, and that the mean number of its vibrations in a second of time is between five and six millions of millions. This velocity is utterly incomprehensible, quite as much as if it were increased one hundred million fold. Even in the first case we must be content with the result of calculation, which is far more credible and less obnoxious to objections than the theory which explains the phenomenon of light as the effect of matter projected perpetually from a luminous body at the rate of 186,000 miles per second. To tolerate that theory in preference to the theory of undulations in a quiescent fluid, betrays a mind to which the simplicity of truth has no beauty, and which is liable to accept, without cavil, the most unreasonable hypotheses, while ignoring those which seek to divest nature of all mystery.

But we are not writing for the mere man of science;

for it may be said of him as of Ephraim of old, "He is joined to idols, let him alone." In fact, from the experience of the author, he has no idea that the labor of forty years which is here so summarily and briefly presented will be *honored* by a perusal by those who have (in the face of repeated efforts to call their attention to different sections of his theory) steadily ignored it, as if there was danger in mentioning its claims. And no wonder; for he has quietly looked on for thirty years and seen many portions of that theory bedizened with a little paint to change their expression, and then adopted by strangers as their legitimate offspring.*

Resting implicitly on the above general conclusions, we are prepared to follow out this reasoning and apply it to the questions before us. The solar system, then, is not a mere skeleton or frame-work of ponderable matter, but one vast mass of substantial elements united as a whole, in which each part is connected with every other part, not only through the gravitating principle, but through material ties of far more power when circumstances conspire to call it forth—a bond of nervous sympathy which, at almost the same moment, thrills through the whole body of which the sun is the head and heart and life.

No matter what may be the relation between the ethereal matter and the bodies of the planets and satellites in units of inertia, they are nevertheless related. From the probable velocity of vibration approximately inferred from the velocity of the waves of light, the density of the ether has been calculated by Sir W. Thompson, which calculation shows that one cubic foot of ether at the mean distance of the earth contains not less than the $\frac{1}{154,000,000,000,000,000}$ of a pound of matter. Prof. Harkness gives the fraction expressing the density of the interplanetary medium as $\frac{1}{250,000,000,000,000}$ of the density of atmos-

* See note A in Appendix.

pheric air, and as a cubic foot weighs 527 grains, or $\frac{1}{13.28}$ of a pound of 7,000 grains, a cubic foot of this interplanetary medium would—if it were ponderable—weigh in round numbers $\frac{1}{3,320,000,000,000,000}$ of one pound. But the previous calculation gives only $\frac{1}{156,000,000,000,000,000}$ of one pound, which is only about $\frac{1}{50,000}$ of that obtained by Prof. Harkness.

But there are other ways of getting an approximate, or rather a speculative, value of the density of the ether, by recognizing its affinity to other gases and calculating its atomic weight, and this gives the fraction of one million millionth of the density of air, which would be 250 times greater than Prof. Harkness gives, or a cubic foot would weigh less than $\frac{1}{13,000,000,000,000}$ of a pound.

This shows how uncertain the data of such calculations are. But whatever the density of the ether *it possesses inertia*, which being unrestrained by the gravitating principle, or attraction of a central force, is sufficient to account for all prominent solar phenomena. The reader's attention is particularly invited to this point. It is one of those fundamental facts whose wide application and important bearing on so many questions in astronomy ought to have commanded attention, if not recognition, long ago.

One of the high priests of modern science whose eloquence the writer admires as much as he respects his knowledge of *nature*, cites a case where the action of this ethereal medium and the influence of its specific heat is displayed under another name, which, if not exaggerated, proves at least the tremendous power which nature wields through its agency. "I have seen," says Prof. Tyndall, "the stone avalanches of the Alps which smoke and thunder down the declivities with a vehemence almost sufficient to stun the observer. I have also seen snowflakes descending so softly as not to hurt the fragile spangles of which they were composed; yet to produce

from aqueous vapor a quantity of that tender material which a child could carry, demands an exertion of energy competent to gather up the shattered blocks of the largest stone avalanches I have ever seen, and pitch them to twice the height from which they fell."

Reduce that force a thousand times and it still shows what an unlimited range of phenomena is involved in that question of the specific heat of the ether. Generally the specific heat of matter in its simplest form is inversely as its atomic weight. If there be a few discrepancies they do not vitiate the great majority of observed coincidences. Now what is this but an indorsement by nature of the great postulate, that all physical phenomena are due to mechanical causes. For as momentum is the product of matter and motion, and heat is but the measure of the motion of the molecules of a body, giving, *cæteris paribus*, to equal spaces equal powers, we can conceive what a tremendous cooling or heating influence the ether must exert on commingling with ponderable matter. To this we owe our rains and storms and ever-changing temperature; for the temperature of the ether surrounding us has been determined to be as much as 200° Fahrenheit below zero. And whenever the electric tension of the solid earth or of its atmosphere is disturbed, the restoration of the equilibrium comes from above. This is remarkably exemplified during the routine of a storm. At the beginning the temperature rises with increasing clouds. At the close the temperature falls with clearing weather. What is passing on the earth is but the pigmy shadow of what is doing in the sun. The same element is at work, called into action by the same conditions and governed by the same laws. We shall not enter into any vindication of our course in treating this ethereal medium as we would a ponderable gas. If we had a gas at common temperatures and pressures no denser than the ether (*i.e.*, having no more actual matter in a given space), that gas would have the same specific heat as the ether, no

matter whether matter be atomic or not, and thus regarding it, we dismiss the discussion of that question as superfluous.

In the solar vortex, then, we have, besides the planets, a medium which owes no obedience to the central force. Its rotary motion with the same velocity as the planets begets centrifugal force in all its vast extent, perhaps reaching along its equatorial plane (corresponding probably with the equatorial plane of the sun) to distances ten times greater than the radius of the orbit of Neptune. Every particle of this revolving mass is striving to escape outward from the centre to the circumference, with a velocity ranging as the square roots of the distances from the centre, taken inversely. We read in our daily papers of fatal accidents occurring from the bursting of fly-wheels and grindstones, caused by an undue velocity imparted to them, by which the force of cohesion is overcome. Is it not strange that no importance has ever been attached to the momentum of the fluid of space, necessarily partaking of the orbital motion of the planets? It would be lost time to compute what this force could be compared with, as we have seen that the density of the ethereal medium, as computed by different observers of equal ability, may vary as fifty millions to one. But that it must exceed the centrifugal force of all the planets in the solar system is evident at a glance.

So far, then, as its relative density is concerned, instead of regarding that density as greatest near the sun, as if it were a ponderable fluid, we find it must then be at its least degree of density unless some other condition interferes. In other words, its own vorticose motion must rarefy the matter in the interior of the vortex, in that inverse proportion which we take in the ratio of the square roots of the distances, subject to the exception above alluded to.

Now, even suppose that the whole vast *territory* of the sun were inclosed in an infinitely strong cylinder and ro-

tation given to it, there would be condensation at the circumference and rarefaction at the centre as long as the rotation was kept up. But in the free space of heaven—in an ocean of infinite extent—there could only be rarefaction at the centre, and then only in degree, depending on the relation between the average velocity and the axial extent of the cylindrical vortex. The circumferential outflow would be made up by the influx of an axial or polar current, provided that influx were not retarded by the length or narrowness of the polar channel. It would perhaps be safe to consider the current of influx down both poles (for, of course, there would be two opposite currents) to be equal, axially, to many times the diameter, taking analogy for our guide. In the vorticose motions of our atmosphere, as in the water-spout or in the whirlwind, the diameters are small in comparison with the height of the visible column of dust or vapor; but whatever the difference may be, if our reasoning be correct, the influx is never quite sufficient to restore the equilibrium of the interior, even if the inflowing stream moves with planetary velocity, and there is, consequently, always rarefaction around the centre, and a stream from the axis rushing outward along the equatorial plane, whose velocity is exhibited in the form and extent of comets' tails, which always point away from the sun, with only slight deviations; but we shall not dwell on this subject here, but treat it fully in another chapter.

Now, without knowing the absolute velocity of this current, which we shall show varies at different times, we may, on certain assumptions, determine the *relative* velocity at different distances; for if this stream be radiated in planes parallel to the ecliptic or equatorial plane of the sun, its velocity ought to diminish with the distances from the axis. Considering, however, that as the ether is supposed to rotate in the same time as the planets, we have found that its density increases outward in the ratio of the square roots of the distances from the centre; or, in other

words, the rarefaction produced by the centrifugal force of rotation is inversely in that ratio, and thus an equilibrium is produced. If, however, the velocity of the outflowing stream, irrespective of the density, is as the distances inversely, it is still further diminished by absorption in the ratio of that density and distances inversely; but the *force* of this stream is as the square of this compounded ratio, or as the cubes of the distances from the centre.

But we must not forget that if the velocity be diminished by absorption with recess from the centre, its force will be increased by its density, so that the true force of the stream will be directly as the square roots and inversely as the cubes, or as the 2.5th power of the distances inversely. Now so far as the influence of such an expulsive stream is concerned, it only can diminish the central gravitation by a certain amount depending on the inverse ratio of the squares of the distances, for this corresponds to the Newtonian law—both acting in opposite directions; but while this is the case in one portion of the above ratio, that part of the force which arises from the inverse ratio of the square roots of the distances is uncompensated, and is, *pro tanto*, a real perturbation in the planetary motions. While the whole force compounded of the two, acts as an expulsive (or if preferred a repulsive) agent in radial lines from the axis of the vortex, available in the explanation of cometary and other phenomena. For a more thorough discussion of the law of the radial stream, the reader is referred to the author's "Outlines of a Mechanical Theory of Storms." (pp. 160–180).

In this inexhaustible supply of electricity streaming perpetually from the sun, we find a key to unlock many of nature's secrets, while by the ever-changing position of the planets, the sun is supplied with that kinetic and *radiatable* energy, which, in turn, he dispenses to his numerous family, spreading abroad with liberal hand the

riches of light and heat and life, to each according to its wants; for it is in, and by the sun, they live, and move, and have their being. If man was made in the image of God, can we not say, also, that the sun, with his retinue of worlds, was made in the image of man? The noblest part of man—the head—is just as dependent on the members, as we shall show the sun to be dependent on the orbs which are united to him by the bond of physical attraction. Not a tremor can affect the head, without thrilling the whole body to the finger ends. No internal jars can affect the sun without being felt by the remotest planets, for without planets the sun would be inert and motionless. The solar system is one body, and all its members essential to the well being of the head, as the head is to the members.

Science may condemn such notions, and refuse to see anything but dead matter galvanized into a chance existence of brief duration, rather than admit the evidence of wisdom and design in the mechanical arrangements of our system; and hence the many bungling distortions advanced as discoveries worthy of our confidence. But common sense rebels at such drafts made upon our ignorance, and often sinks into the apathy of doubt, for want of a healthy theory that can, in simple terms, reconcile known facts with intelligible principles, without ignoring the presence of a Guiding Hand.

If we glance backwards along the world's history, we rarely find a theory of nature which does not give an explanation of its phenomena utterly unworthy of even common intelligence; bringing down the fabric of the universe to our own puny level and limiting the resources of Omniscience.

Passing over the absurdities of the savage era, we find, when men began to reason, their efforts always fell short of the truth—all first efforts to determine parallax failed in this sense—and even those theories based on precise observations were contrivances of the most clumsy and

unwieldy order, as in the case of the cycles and epicycles of Ptolemy. And it is so at the present day. In trying to elucidate some natural problem by a sufficient cause, inherent in inert matter, we propose theories incompatible with those equally good which are devised to explain other phenomena. Natural science has thus become a patchwork of many colors. A building of rambling additions without connections, doomed to collapse by its own *oppositions*, in company with all other merely human devices, "in the day of the great slaughter when the towers fall."

Now, when we look around us, we see no evidence of lack of means, no signs of insufficiency in available forces; but on the contrary, illimitable profusion wherever we turn our eyes. In the heavens, the telescope can give no limits to the number of created worlds. If there be densely compacted clusters of stars, their proximity is not for lack of room; for we have not the shadow of a reason for believing that one portion of infinite space differs from any other portion, or for supposing that if our sun and his progeny were transported into a region of stars, now shining beyond the ken of man in the deep unknown, it would make any difference to the world's dependent upon it. Speaking in the language of finite ideas, there is, and can be, no difference in the *climate* of infinite space from the poles to the equator.

If we look into our own system we see arrangements the very contrary of what human wisdom would suggest, regarding the sun as the source of life to the worlds around. The planets are placed at increasing distances from each other, the more distant they are from the sun; and on this account the largest planets may intercept less solar radiation than the smallest placed at a less distance. The diameter of Jupiter is about eleven times the diameter of the earth and their surfaces exposed to the sun as 120 to 1, yet Jupiter only intercepts the solar rays in the ratio of 5 to 1 in consequence of its greater dis-

tance. Now what a prodigal waste of light and heat there is in the solar system. In *one day* a power sufficient to propel our cars and ships and supply every machine with motion during the whole existence of man upon the earth is apparently thrown away. And when we come to figures we find that *less* than the two hundred millionth of the whole radiant energies of the sun is utilized by all the planets of our system.

Suppose the revenues of the United States be 200,000,000 of dollars annually all, apparently, wasted and thrown away except one solitary dollar, and that dollar was found sufficient for all government purposes; would it not be a pertinent question to ask why such unnecessary waste? In the case of the sun the answer would be: Because the giver is *infinitely* rich and ever willing to give. Why then should our conceptions of the universe be cramped by any procrustean rule, and a limit be attached to force any more than to space. Our great principle is—*That the great ethereal ocean fills infinite space with matter in motion, and constitutes an illimitable reservoir of kinetic and potential energy which will coexist in their present ratio of equality through the ages to come as they have done in the past*, according to human conception. He "who laid the foundations of the earth that it should not be removed forever," needs no vindication of His works at the hands of science; and our labored calculations, to prove that an inevitable catastrophe awaits every sun and planet in the universe by the extinction of its light and the loss of its heat, are worse than superfluous, they stigmatize creation as a failure. Our present effort to expose this folly may perhaps be obnoxious to the same charge; but our error proceeds from an honest zeal, at least, and may perhaps assist in dispelling some of the delusions which so easily take root in the natural heart.

Looking forwards to the *end* we are equally troubled to formulate a plan by which a beginning may be accounted for. How did our system originally come into being? If

as a nebula, what disengaged the planetary masses from the centre, what set them revolving on the same course and in the same plane? What caused their rotation and the rotation of the satellites in the same direction? How many years has the present state of things existed and how long will it exist? These are questions better left in abeyance, while so many practical problems are pressing for a solution which, when correctly solved, will, perhaps, throw a light on the future and the past, which will convince us of the irrelevancy of all such idle questions.

CHAPTER II.

THE SOLAR SURFACE.

THE problems presented by the solar surface are justly deemed by men of science, not only of paramount importance, but also of excessive difficulty. Since the telescope first revealed spots on the sun, other well established facts have been ascertained, so that we not only have to seek for a satisfactory explanation of their origin, but also of the cause of their periodical maxima and minima of frequency, as well as of their limitation to certain zones of solar latitude. There must be a physical cause for the spots, and that cause must itself have its maximum and minimum activity, both in time and place, and no explanation of these three phenomena can possibly satisfy, unless they be referred to one and the same cause.

But there are many preliminary questions to settle before we can give an intelligent opinion on the numerous collateral subjects which are inextricably involved in the decision; and we must show our hands on all those points, with the earnest desire to arrive at the truth regardless of either hostile or friendly criticism.

The first question which presents itself is, what do we know about the sun—what is its distance—what its size or volume—its mass and density—its heat and light—and whether it is losing the latter and at what rate? To answer these questions it is necessary to know first our distance from the sun. In elementary books, of course, this distance has some settled value, but in truth, it is one of the most uncertain quantities in astronomy, although of fundamental consequence. Brevity and con-

densation, however, are our objects, and we shall not describe the various processes by which this element has been determined, all which coincide in giving a mean parallax of between 8″.5 and 9″.5. Two methods, however, may be mentioned which would undoubtedly command respect, if they could be made to harmonize with each other. These are 1st, the transit of Venus, and 2nd, differential observations of Mars at opposition. But Mars gives a greater parallax than Venus, and has the advantage of frequent repetition, whereas Venus is only seen during alternate transits at intervals of eight and a hundred years. In 1761 the transit gave 8″.61, or a distance of nearly 94,500,000 miles. Prof. Encke deduced a different parallax by combining the two results obtained by observers in 1761 and 1769, giving 8″.5776 or 95,274,000 miles.

In 1854 the author published his convictions that the ethereal medium and the law of its density, introduced a disturbing element into the question of parallax, which might reconcile the results obtained from Venus with those obtained from Mars, recording them in these words; "Let not astronomers, therefore, be too sure that there is not a modifying cause independent of gravitation, which they will yet have to recognize." (Outlines p. 178).

While the scientific world was content to adopt the old Enckian value of 8″.5776 or 95,274,000 miles for forty years, recently they have run into the opposite extreme on the authority of Hansen, Le Verrier and Stone, who give it as 8″.9—the author, on the contrary, has long contended for the value 8″.8 deriving it from the results obtained from Venus and Mars conjointly, by correcting them for an expulsive action of the great solar stream, dependent on the square roots of the distances inversely. This gives about 93,000,000 miles for the sun's mean distance, and a semi-diameter in round numbers of 434,000 miles — taking the suns mean angular semi-diameter as 16′.2″.5, which he thinks nearer the truth than 16′.2″.

In view of the many discrepancies existing, the author was hopeful of getting observations which he might use with those of others in determining this question for himself, and therefore prepared himself for the recent transit of Dec. 6th, 1882, and considered himself very reasonably successful. An occurrence of this kind which will not again happen, either in this century or the next, he may be pardoned for recording as something worth preserving. And a communication was addressed to the Transit of Venus Commission at Washington embracing the facts observed and recorded at the time without change or embellishment. It was sent by the author as a possible contribution, and it was so accepted by the Commission and courteously acknowledged.

(See Appendix note C.)

As yet no attempt has been made by the author to utilize these observations to confirm the numbers representing the parallax, distance, and semi-diameter; but the numbers designated above cannot be far from the truth, and we shall so consider them in discussing those questions affected by them.

The sun then is an immense globe whose diameter is 868,000 miles. This is about one hundred and ten times greater in diameter than the earth, whose mean density is six times the density of water, while her average superficial layers are not more than half that density—requiring a condensation at the centre, or in her central parts, greater than gold or platinum to bring up her whole volume to six times the weight of an equal bulk of water. Yet the sun, with a central force 28 times greater and a range of vertical pressure over a hundred times greater, has only a mean density of one-quarter that of the earth. As gravitation, which produces pressure in solids, liquids, and gases is a force, which, in this case, does not seem to be verified by facts, we must look to some other force operating expansively. Now, heat is that force, and *a priori*, we readily attribute to the sun a temperature far

exceeding the greatest heat which man can produce. But there is sometimes a trifling oversight in estimating what the temperature of the solar surface is. As the heat from a *distant* source is inversely as the squares of the distances, the visible disc or area is correctly taken in the same ratio; the visible diameter is also the real diameter and is therefore constant; but this relation cannot obtain to the very surface of the sun; for, if so, we should have a temperature at one foot from the sun's surface exceeding that of its noonday effect upon the earth, in the ratio of the squares of the distances inversely in feet, as 240,000,000,000,000,000,000,000 to 1. Every square foot of the visible disc contributes its influence; but when this area is diminished by excessive proximity, a maximum effect is produced long before we arrive at the solar surface. Rosetti makes the effective temperature of the solar surface 18,000° Fahrenheit. It is so also in reference to the *light* of the sun, yet, even Mr. Proctor (who is usually so accurate in his figures) takes this very case and applies the ascertained ratio of "the intrinsic brilliancy" between the sun's rays and 32,700 sperm candles. "In order to conceive the real amount of light to which a body close by the sun—within a foot, say, of the photosphere, would be exposed, we must conceive the amount of light we receive in the full splendor of a summer's day increased in the same proportion that the whole hemisphere of the sky exceeds the solar disc." The sun's radiation on the surface of the earth is 44,680 times less than at the sun itself; but the effect would be nearly seven times this, if the whole hemisphere were a sun of the same intensity as the natural sun and taking his diameter as half a degree, or over 300,000 to 1. The temperature of the sun, however, is amply sufficient to justify the inference that it is the force which counteracts the enormous tendency to condensation, and renders that great body but a little heavier than a huge globe of water. This admission drives us to another conclusion, viz.: that,

neither solids nor liquids constitute any considerable portion of the solar globe. But in shunning Charybdis we rush into the jaws of Scylla; for if we contend that the sun is a mere globe of gas we are confronted by the law of Mariotte, which, followed to the centre, would, under ordinary conditions, reduce any known gas to such dimensions as would give it a specific gravity exceeding our densest elements, and so would bring up its mass to a value which would be a virtual denial of the Newtonian law. In adhering to *that* law, we might suppose the body of the sun to be composed of unknown liquids or solids of low specific gravity, and ignore the real temperature; but we have no analogies to warrant the supposition that *incompressible* liquids or solids exist in nature, and, when we reflect on the vast distance between the surface and centre we are debarred from accepting it. There seems no way of escape then from this dilemma but by admitting that our central luminary is a globe of gas at a temperature inconceivably great, and that that gas is principally hydrogen with other terrestrial elements in the state of vapor; pretty uniformly mingled throughout the whole mass. And hence, the definiteness and invariability of the solar spectrum, which otherwise might be expected to show differences at different times and in different latitudes and longitudes, according to differences in the elements of different localities.

Another consequence of the position here assumed is the impossibility of determining the exact period of rotation of the sun.

Spots observed in one solar latitude give a different rotation to that of another latitude—those nearest the solar equator giving a shorter period than those in higher latitudes. In fact, to expect a state of permanent quiescence in the solar orb is unscientific, to say the least, as its rotation is real as well as its orbital motion. Vast as are the dimensions of the sun, its interior gas is often coming to the surface if our position be correct, and con-

sequently, while the mean temperature of the whole mass preserves a certain average by the action of internal and external currents, those very currents will account for differences in temperature, both in time and place, such as have been determined by observation. And thus another fact is reconciled with probability.

The visible covering of the sun is designated as the photosphere from whence the light proceeds. Outside this, the spectroscope reveals a scarlet band of no great density, but which is rendered palpable by the extent of the visual ray of many thousand miles. Just as in our clearest atmosphere the color of the western sky, after sunset, glows with red light reflected from the particles of vapor on which the sun yet shines, which, by reduplication, become visible, while higher up they are so scant in number as scarcely to tinge the same atmosphere with color. This is called the chromosphere, from its being vividly colored, and extends upwards from the photosphere as much as 10″ or nearly 5,000 miles. From this colored shell emanate those jets and prominences which, by their fantastic forms and rapid motions, have invested the spectroscope with such fascination in the eyes of many. This chromosphere or outer shell, however, is totally invisible when looked at from above. All the mottlings, and pores, and granules, and spots, and faculæ of the surface, are seen through this shell, and, although, the umbra of a spot is sometimes tinged with red, yet, as a general fact, it may be asserted that, the vertical column of 5,000 miles or less, does not make its presence known by the faintest shade of color. On page 27 (Fig. 4), is the representation of a spot seen April 22, 1882, which became gradually overspread with a pretty thick veil of a brick-red color, until fully one-half of this peculiar spot was covered. The spot was a long oval surrounded by a wide margin of photosphere perfectly white, and outside this an irregular penumbra connected with other spots of the same group. This white margin was

FIG. 4.—RED SPOT SEEN APRIL 22D, 1882, INDICATED BY THE ARROW.

not irregular in form, or contorted like faculæ, but had steady well-defined outlines, and yet was bright as a facula. The singular part of this appearance was the utter invisibility of the colored veil on the white margin surrounding the spot, and its complete accommodation to the size and shape of that half of the umbra which was covered by it. The impression was that the umbra and the veil were connected, and that the latter had nothing to do with the chromosphere or with the penumbra. It is to be hoped that others saw the same spot at the same time—3 P.M. of April 22, 1882, in Long. 81° 37′ W.

The rotation of a fluid globe whose strata are of varying density from zero to a maximum, competent to give an average density of 0.25 of the mean density of the earth for the whole globe, is a problem which would require for its solution a knowledge of the temperature of the strata at different depths; but this general conclusion may be safely drawn, that such rotation will beget a centrifugal force at the equator, diminishing towards the poles as the squares of the cosines of the latitudes. And that, in consequence, there will be a constant superficial polar current setting towards the equator, so that the equatorial diameter should exceed the polar; but, in consequence of its extreme slowness and the ill-defined boundary of the solar disc, it has never been detected.

That such oblateness exists must, necessarily, follow from the rotation, even, if the sun were solid to the core, in obedience to dynamical laws. It may, perhaps, be argued with Sir John Herschel, who, in speaking of the solar spots, observes, "That the tranquillity of the sun's polar as compared with his equatorial regions (if his spots be really atmospheric), cannot be accounted for by its rotation on its axis only, but must arise from some cause external to the sun, as we see the belts of Jupiter and Saturn, and our trade winds, arise from a cause external (?) to these planets, combining itself with their

rotations, which, *alone*, can produce no motions when once the form of equilibrium is attained." Against such a questionable dogma, the author (with all due respect for so great an authority as Sir John Herschel), protests, and contends that, the particles of a fluid globe in rotation are in perpetual motion, superficially and internally, and, although, when the particles of a gas are brought nearer by compression, there is a certain action, called attraction, which partakes in some degree of the capillary attraction of liquids, or even of the attraction of cohesion, and renders a gas more viscous than when not compressed; yet this only retards the motion of its particles by a quantity which is a function of that compression, and only partially interferes with the principle contended for above. Admit that, in a fluid globe in rotation, "the form of equilibrium is attained," yet the polar current still moves on towards the equator, as Capt. Parry found in his efforts to get to the northward of Spitzbergen over the frozen sea against a current which baffled all his efforts. Much more will there be a steady current from the poles of a fluid globe towards the equator, not, however, in spherical lines, but in waves. No matter how small the excess of protuberance is above the normal amount, this excess, combined with another more potent cause, gives rise to an inequality of pressure at the equator, and to a current downwards, which again curves upward in higher latitudes. And this process must be general throughout the whole vast volume of the sun.

If we follow a particle in its leisurely migrations, we see it emerging to the surface (near the north pole for instance) to begin its journey to the equator. Now, bearing in mind that the whole globe is in rotation with a velocity in each particular latitude due to this constant transfer and interchange of polar and equatorial motions, the particle we are following descends into lower latitudes with the rotary sluggishness of the polar circles which it has left, and necessarily falls behind, or tends to fall behind,

in those latitudes at which it has arrived. But while proceeding south, it is all the time acquiring a greater rotative velocity from contact with strata which have been accelerated by friction with still lower layers. As the particle progresses south, however, the cosines increase more and more slowly; so that, before it arrives within 11° of the equator, the cosine only lacks $\frac{1}{50}$ of being equal to the radius.

Now, unfortunately, the means of getting even an approximate value of the sun's rotation utterly fails in latitudes above 40°, as spots are never (or very rarely) seen above that latitude, and it is on the spots we have to rely as the only tolerably stationary markings for determining the motion of the surface. From such observations a fair estimate has been made of the rotation of the sun in different latitudes (beginning at the equator) by Mr. Carrington, who has devoted much time to the study of the solar orb; but while the author yields to him the palm of ability, he cannot acknowledge his inferiority in zeal or in patience; for the sun was an especial study with him before Mr. Carrington was born, and he prefers his own approximations.

Mr. Carrington from 5,000 observations obtained different estimates, as may be seen below, but where so much is empirical a reliance on formulæ for which no reason can be given, is calculated to mislead rather than to instruct, and our business is to exhibit a rational connection between the cause and the effect. Now as the impelling power arises from the gradually increasing density of the layers, which in an elastic gas, is as the pressure of the superincumbent strata, whatever modification the enormous temperature of the sun and its possibly (not probably) diminishing ratio downwards may make, the density will still be as the pressure. There is therefore an acceleration of motion upwards by expansion, and a necessary cooling, while a contrary effect is produced at the equator. But there is another reason why the equatorial regions

are the hottest, as Secchi has observed, and as we shall show in its proper place.

But it may be necessary to be a little more explicit about the dynamical consequences of a fluid globe in rotation such as we have reason to regard the condition of the sun.

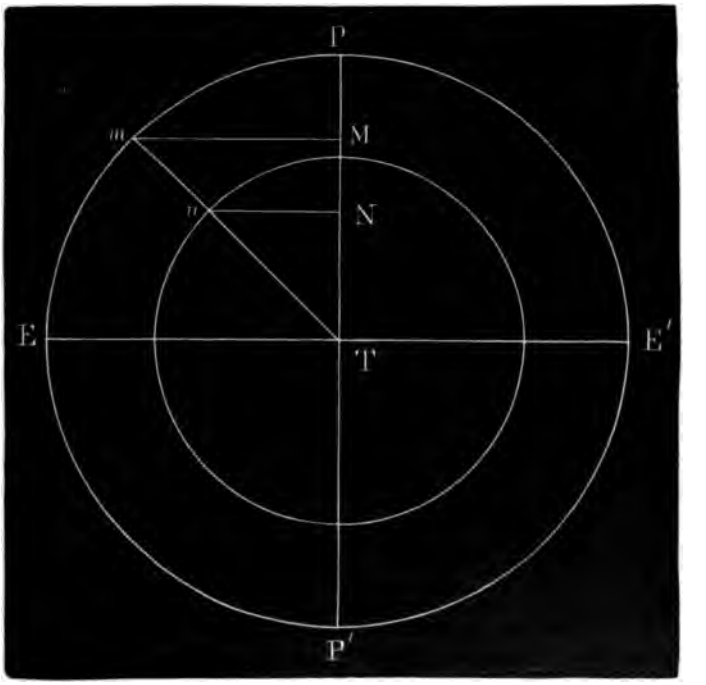

Fig. 5.—Diagram Illustrating the Course of Gaseous Currents in the Sun.

Let PP' represent the north and south poles of the sun, and EE' the solar equator, and m and n two particles of matter at different depths below the surface. Now while the inertia of the two particles remains unchanged, and their axifugal tendencies are as the lines Mm and Nn, if the sun were a homogeneous body of matter of invariable density, the central forces would be also as the lines Tm and Tn, and the two particles would be in equilibrio.

But in a globe of compressible gas the density at n is greater than at m. Call the surface density d, and the density at $n = D$, the ratio of the central force is as dm to Dn, which by the theory is much greater in proportion to the axifugal force at n.

It is obvious, then, that the axifugal forces are not balanced by the respective central forces, inasmuch as the average density of the globe n, N, T, is greater than the average density of the globe m, M, T, and therefore the particle n meets an adverse current, caused by the accumulation of matter at the equator which deranges the equilibrium; and this can only be restored by forcing back the particle n towards the poles by the preponderance of the force urging the superficial layers to the equator. If, then, we can ascertain the rotation in three or four different latitudes, we can, from the difference of rate observed, determine roughly the rate for all other latitudes, leaving out any temporary or accidental influences, such as cyclonic, orbital, repulsive, or other motions which are not dependent on the latitude. Of course we must be content with probabilities in lieu of certainties, yet by general consent the period at the equator is between 24½ and 25 days, and we shall, therefore, call it:

At Equator.....					24	days.	18 hours.
Latitude 10° we put down as.....					25	"	6 "
"	20°	"	"	".....	25	"	18 "
"	30°	"	"	".....	26	"	12 "
					102	"	6 "

$$\text{mean } \frac{102.25}{4} = 25.56 \text{ days.}$$

Mr. Carrington makes it from his observations but little over 25 days. Now calling X the rate per day and l, the latitude, we obtain the following simple formula satisfying the above numbers. The rates represented above as far as reliable observations extend, justify us in putting the difference of velocity between the poles and the equator

as 100′ per day multiplied by the sine of the latitude as in the table below:

$X = 872' - 100'$ SIN. l.

LAT. OF SPOTS.	ROTATION PERIOD.	RATE PER DAY.	RATE PER FORMULA.
0°	24.75 days.	872′	872′
5			
10	25.25 "	855	855
15			
20	25.75 "	839	838
25			
30	26.50 "	815	822
70			
90	28.00 "	771.5	772

So we have only to take the two first figures of the natural sines from the Table and subtract from 872′, and we get the rate of rotation for any solar latitude. In this way we have formed the columns, comparing the results obtained by our formula with Mr. Carrington's; but remembering that there are no measures in astronomy less trustworthy than the measure of the rate of rotation of a solar spot. Mr. Carrington's Table below is from Mr. Proctor's book.

NORTHERN HEMISPHERE.					SOUTHERN HEMISPHERE.				
LATITUDE OF SPOTS OBSERVED.	PERIOD OF ROTATION.			RATE PER DAY.	LATITUDE OF SPOTS OBSERVED.	PERIOD OF ROTATION.			RATE PER DAY.
	d.	*h.*	*m.*			*d.*	*h.*	*m.*	
Equator.	*24	2	11	867′	Equator.	*24	2	11	867′
5°	25	0	42	863	5°	24	23	18	865
10	25	8	29	859	10	25	5	35	856
15	25	9	10	851	15	25	13	31	845
20	25	17	8	840	20	25	17	52	839
30	26	9	46	824	30	26	12	50	814
50	27	10	41	787	50	28	11	0	759

* There is manifestly an error in the period here, as 24 days, 2 hours, 11 minutes ought to be 24 days, 22 hours, 11 minutes, to correspond to a rate of 867′ per day. The author has not had an opportunity of seeing Mr. Carrington's book.

This Table, which exhibits the rate of southern spots separately, reveals a fact as novel as it is instructive. The author regards it as a real phenomenon, which will receive its elucidation from a comparison of the data with the position of the earth in its orbit, with reference to the inclination of the plane of the solar vortex with the plane of the sun's equator, and to the longitude of the centre of gravity of the system. Meanwhile we will consider that the whole equatorial volume of the sun, between the parallels of 45° north and south, embracing over seven-eights of the whole mass, is rotating faster than the remainder of the sphere, so that a mass at the equator (supposing it possible for any matter to preserve a permanent position under such circumstances), will rotate 28 times for the polar regions 25 times, or inversely as the times. It will be noted that there is a discrepancy in the first numbers of our table as compared with Mr. Carrington's; but his number for the equator was based on altogether insufficient data. Equatorial spots being about as rare as the transits of Venus. Our formula, derived from a progression observed in the most prolific latitudes, is far more trustworthy, as well as simple and convenient. The maximum difference between the equator and the poles being just 100′ as above stated. In order the better to compare Mr. Carrington's formula with our own, the observed numbers for the Northern and Southern hemispheres are placed below, side by side, with the numbers derived from both formulas, wherein the general agreement is exhibited, while at the same time, in high latitudes, there is an anomaly apparent, perhaps due to a serious error in the deduced results of observation:

NORTH LAT.	OBSERVED AND COMPUTED BY CARRINGTON'S FORMULA.		COMP. BY OUR OWN FORMULA.	SOUTH LAT.	OBSERVED AND COMPUTED BY CARRINGTON'S FORMULA.		COMP. BY OUR OWN FORMULA.
0°	867′	866′	872′	0°	867′	865′	872′
5	863	863	865	5	865	863	862
10	859	857	857	10	856	857	853
15	851	850	848	15	845	850	845
20	840	840	840	20	839	840	836
30	824	816	824	30	814	816	820
40		789	809	40		789	807
45		775	802	45	*759	775	800
50	*787	762	797	50		762	794
70		717	779	70		717	776
90		700	772	90		700	772

* Single observations, and therefore unreliable.

The diagram below represents the sun, cut by a plane passing through his poles and his centre at right angles to the plane of the observer, and is intended to guard against any misconception of our meaning when we argue that a particle of matter in the superficial layers of the sun, starting at the poles, tends toward a lower latitude by the mere action of the greater unbalanced centrifugal force of rotation at the surface than at lower levels—*PP′* being the poles and *EE′* the equator.

But we do not assimilate it to the icebergs of Baffin's Bay passing to the south and west on a surface current. In a boiling liquid we may follow grains of matter in a continual whirl of circles; but a liquid—even if we could apply the heat in a suitable manner—is but a precarious guide to the internal motions of a gas. The most striking and available analogy is found in the dense coal black convolutions emanating from a steamer's smoke-stack when *firing up* with fresh coal. Wheels within wheels in endless succession, crowd and jostle each other without

interference or apparent friction, and move on in beautiful and graceful harmony. If these be closely watched, we discover a series of ring vortices expanding as they progress. Their origin is the friction of the interior of the cylindrical smoke-stack, just as the internal surface of a cannon gives out a beautiful ring of smoke when that surface has been greased before firing. It is true that

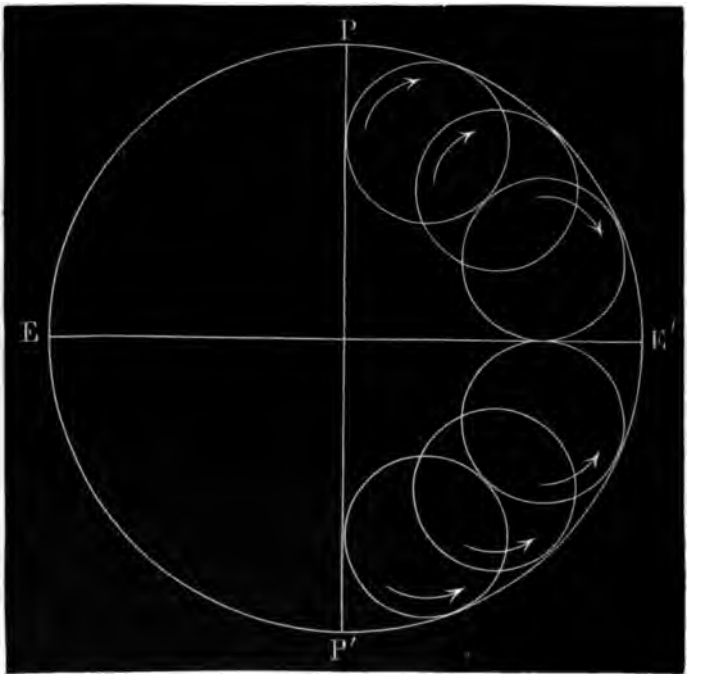

FIG. 6.—DIAGRAM ILLUSTRATING CIRCULATION IN THE BODY OF THE SUN.

the axis of the sun is not a gigantic smoke-stack; but, suppose the gaseous matter of the centre to pass along the axis to the poles, the friction of the surrounding parts, not partaking of the same amount of that motion, would act as effectually in producing that vorticose ring motion as the steamer's iron cylinder. Escaping at the poles, and crowded by the current behind, the ring would ex-

pand and reverse its motion as a ring of moving gas; but its vorticose motion would not be changed. The outer particles of the ring would always be moving toward the equator, and the inner toward the poles; and thus such a gaseous globe as we suppose the sun to be, will be in a state of continual circulation as two systems of interlacing ring vortices, north and south of the equator. And should there not be an exact distribution of matter in the two hemispheres (as would appear from Mr. Carrington's determination of the rate of rotation in both the northern and southern hemispheres), the effect is only (as appears from our formula) to give a difference of one degree between the physical and geometrical equators. In other words, our formula satisfies the observations within the limits of error by placing the equator of maximum rotation in 1° of north solar latitude. But this observed difference of rotation is due to this very motion we are considering, and of course introduces another motion. While the ring vortices in the northern hemisphere are progressing south, and expanding as they progress, they are mingling with matter which has a greater velocity of rotation eastward; so that the rings move around from east to west in their own plane, but diminishing their speed as they approach the equator by a kind of spiral or screw motion, which reaches its maximum at the equator of rotation, to begin again the same endless round of circulation.

But the illustration we have used must not be pressed too closely. The matter composing one of these ring vortices is continually changing, neither is such a vortex composed of a definite number of particles, nor is it constant in velocity or in the ratio of volume to diameter.

The analogy is only so far true as representing the general route of a particle, and the direction of its progress, by a series of revolutions as if it were part of a vast wave whose velocity is a function of its height. The case is of an entirely different character to a question in hydro-

dynamics, where the elevation of the crest of a wave varies reciprocally as the depth of the fluid; for on the sun there is no depth of uniform density. Compression begins at the most attenuated level of a globe of compressible gas, and that compression only suffices—even by rigorously complying with the letter of Mariotte's law—to make up the average density of one fourth of the earth's mean density; showing that we have not begun to comprehend the awful temperature of the lower regions of that stupendous globe. Unless, as we have before remarked, the law of gravitation has some limits, there is no force but that of heat which will account for this result. But it is safest to place implicit confidence in that law, and thereafter the weighty preliminary problem—can there be such a variation in the law *that density is as the pressure*, at extremely high temperatures, as to reconcile this last with the law of gravitation—is the obstacle which bars the way for want of the necessary data.

That the upper limit of the solar atmosphere (a very ambiguous phrase) is a well defined level, we are justified in believing; for, although our own atmosphere at forty-five miles has a density less than the most perfect air-pump can produce in a receiver, yet it is utterly repugnant to the laws of matter and motion to admit that its particles are infinitely divisible. Indeed, the limitation of our atmosphere and the permanence of its pressure, is one of the strongest arguments in favor of the doctrine of ultimate atoms, and as the weight of a body is composed of the gravitation of all its atoms, the earth's attraction on a single atom is as complete to prevent its leaving the central body, as it is on the whole congeries of atoms constituting the atmosphere; so that, as nearly as can be ascertained, at the height of fifty miles the atoms are so far separated by their orbital motion or elasticity that they no longer repel each other, but cling by attraction to the earth, and nothing but an adequate force can drive them away. Otherwise, the atmosphere would be continually

wasting away, until finally its quantity would no longer subserve the wants of breathing animals.

Taking account of the temperature and the probable preponderance of hydrogen in the upper solar strata (and, in fact, throughout the whole spherical space inclosed by the photosphere of the sun), we are justified in inferring that we should find at a depth of fifty miles below the solar surface a much less pressure than 15 lbs. per square inch, as on our own globe, even if allowance is made for the greater gravitating force on the sun, which is twenty-eight times that on the earth. All these facts being taken into consideration, we are disposed to look at the photosphere as but a very little, if any, below the upper level of the gaseous sun, and that the chromosphere of the spectroscopist is but of limited superficial extent as *local* filmy layers of foreign matter, out of place, and of transient endurance; as a cloud of dust is whirled aloft by a summer roadside whirlwind, which obscures the sky for a while, but soon settles back to the level from which it was driven; and, therefore, Sierra is a more appropriate name. We furthermore contend that the rice-grains and willow leaves of the surface, in their permanence and uniformity of size, are the mountain waves of the photosphere generated by the hundred-fold hurricane velocity of that stratum of hydrogen of limited extent, resting on and in part composing the photosphere, the upper limit of which is the region of the dust-clouds, called the chromosphere, or Sierra.

Let the reader, here, bear in mind that we have an immensely difficult task before us. We are attempting to solve the mystery of all solar phenomena by explaining their origin and peculiar phases; by explaining the corona and its changes; by applying the very same principles to the elucidation of the spots; by giving a rational account of the origin of the solar heat and light, with all the other peculiarities which serve to define these problems; he will, therefore, understand that in the above

remarks we are merely preparing the way by these preliminary definitions.

That we are not indulging in exaggeration, we will quote Mr. Proctor, whose work on the "Sun" will well repay the time consumed in its perusal. In taking a general survey of the results so far obtained, and of the magnitude of the task of unraveling the tangled web of solar physics, he remarks (page 429): "But when we attempt to combine these several results, and, further, to determine what the general condition of that orb may be which presents these several features, we recognize at once that a problem of enormous difficulty lies before us. The more we have learned respecting the sun, nay, the more we have learned respecting those physical laws by which we are to interpret solar phenomena, the more insuperable have our difficulties become. It was easy to theorize when as yet but little was known. It was easy to suppose that the few physical laws we imagined we understood sufficed to account for all the phenomena presented by the solar orb. But as one fact after another has been discovered, the true complexity of the problem has been revealed to us; and as the physical laws which it is in our power to discuss and experiment on have been more carefully studied, we have begun to recognize how very limited our experience has hitherto been. It is not too much to say that theories respecting the sun's physical condition, which would have been regarded twenty years since as deserving of careful study, have now no worthier standing in science than the idea of Anaximander that 'the sun is a great vessel filled with fire, at the top of which is an opening through which the fire escapes.'"

But let us not despond. Nature is true to herself, and by nature, let it be ever understood that we mean all those evidences of supreme wisdom which the constitution and laws of matter display in all their greatest and least applications. As knowledge increases, the simplicity of mathematical and geometrical adaptations seem to be lost

sight of, or, rather, faith in those principles is losing ground, and no practical truth or discovery is esteemed unless it owes its origin to a refined analysis, which is only reliable when based upon solid facts, the gleaning of patient experiment and common-sense observations.

If we will follow out the present tendencies of science, we may deduce this inevitable conclusion: In a not very remote age the oppositions of science will come to a climax. The history of the past will be repeated in retrograde order. The people will lose confidence in her teaching. The general cry of *cui bono* will be heard, and neither honor nor profit will be reaped. Meantime man will struggle onward after the *ignes fatui* of science, and be deluded to the end.

It is not within the power of analysis to determine, from such involved motions as we have been contemplating, the true law of rotation for the different solar latitudes; but when there is an observed difference between certain latitudes and that difference is found to vary with the sines, it is certainly not unphilosophical to assume, provisionally, that the integration of all the differentials, if the true question could be stated, would give this identical result for all latitudes. This certainly is no extravagant assumption, nor is it wonderful that the matter of the surface layers of the sun should follow the very law which is observed on the surface of the earth. A particle of air in our atmosphere and a particle of water on the surface of the ocean both recede from the poles and pursue in the northern hemisphere a south-west course. In each case the amount of westing depends on the relative velocities of the particles and of the surface. In this case the angular velocity of the surface is constant in every latitude, but whatever may be the relative absolute velocities in passing from the poles to the equator, the *difference* is a minus quantity, changing with the latitude from unity to zero, and its amount in miles will depend on the ratio between the two velocities. If the earth

were a gaseous globe and no clouds visible in the return equatorial current, a lunarian would determine the rotation for each latitude from the motion of the clouds, which we are supposing would only be visible in the upper polar current, and he would soon find that this difference of rotation is as the sine of the latitude. Now the upper visible clouds on the sun—the spots—present a case very analogous to the one supposed. There is no visible return current to the poles, as this only obtains at lower levels and on that account is invisible; so that we are driven by our observations to conclude that the angular velocity of the sun in different latitudes is (within a very small quantity) equal to $872' - 100'$ sin. L. per day, or roughly, to 25 days at the equator and 28 days at the poles, for a complete rotation. To be precise sin ($L \pm 1^{\circ}$) should be substituted for sin L.

Now, while the author would carefully avoid trespassing on any territory not legitimately his own by priority of discovery, he cannot admit that his theory of the gaseous nature of the whole body of the sun, which he has imparted orally and by letter to many unprejudiced friends for the last twenty years, can justify reclamation from any quarter based on later conclusions; but a remark of Prof. Young in his recent work on the sun, referring to the *equatorial acceleration* as proved by the different rates of rotation, betrays such a palpable leaning to the truth (as we regard it) that it is but just to quote it. He objects to the theory of Sir John Herschel, that this acceleration is due to the "impact of meteoric matter striking the sun's surface, mainly in the neighborhood of the equator, and so continually accelerating its rotation as a boy's peg top is whipped up by the skilfully applied lash," adding the very sensible remark, "that any driving sufficient to establish nearly two days difference between the rotation periods at the equator and at latitude 40° must have produced a very sensible effect within three hundred years. It is more probable that the equatorial

acceleration is connected in some way with *the exchange of matter*, which, if the sun is for the most part gaseous, as now seems likely, must continually be going on *between the outside and inside of the globe.*" (The italics are ours.) It is to the idea of the exchange of matter between the outside and inside of the globe to which the reader's attention is called, as an *independent* corroboration of the author's theory of the gaseous and mobile nature of the solar globe by one who is fully competent to give an opinion. As for the sun being a globe of gas, it seems to the author that no other conclusion should ever have been held, in view of the law of radiant heat and of the well ascertained mass of the sun, unless the Newtonian law be very different from the recognized law of gravitation, and no credit is due to *any one* for holding it. But the *modus agendi* of that other idea—the exchange of matter—is altogether antagonistic to the author's theory. The greatest part of the mass of the sun is included between the parallel planes of 40° of north and 40° of south latitude, and the passage of matter from the poles, whether by a ring vorticose motion or by a more steady surface drift, will cause such matter to lag behind the swifter moving equator; and yet the difference, which is really a retardation when surfaces are compared, may be very much smaller at great depths. But admitting there is a difference of nearly two days between the latitudes stated (as there no doubt is), how can the falling down of condensed vapors, which have been projected from the surface, accelerate the surface from whence they emanated? Unless, indeed, they ascended through an atmosphere having the same rotation at a much higher level and remained long enough to acquire the same velocity before they fell; and even then their deficient velocity when first arriving at that extreme altitude would retard the medium from which they derived their ultimate velocity before ready to fall, while the mother mass would lose by the projection in precisely the same degree. What, then, would

be gained? In the formula of La Place the falling body is not conditioned first to attain the position h, as the point from which it is to fall. In the formula $h = \frac{1}{2} gt^2$, g indicates the force of gravitation, and t the time of falling in seconds. And it is only by assuming as probable the greatest improbabilities that these questions can be mathematically solved. If Prof. Young considers the idea here announced of an interchange of matter between the centre and the surface as an infringement of that or of any other opinions he may have advanced, we hope he will accept as an apology the confession that until May, 1883, we had not seen any of the Professor's published views.

We are perfectly conscious that the foundation we are laying will meet with much adverse criticism; but when the tremendous velocities of the matter composing the solar envelope are admitted (and we cannot see how they can be denied), we are driven to the further admission, that in a fluid terminating in a surface of inconceivable levity there *must* be Andean waves on that ruffled ocean of fire, whose motions must involve this very circular wave-like motion of its particles, excelling our most extravagant computations. And, further, that if the whole solar orb be gaseous, the same kind of ring vortex motion (if that term be admissible) will be propagated, in accordance with the well known *law of forced vibrations*, from the surface to the very centre of the sun. But we may state it in another form; for it is only tantamount to saying that every particle in the sun is rolling over in an independent orbit, and that their orbit diameters and velocities are, probably, inversely in the quadruplicate ratio of the depths. Be this as it may, it will give us a standing ground, by which other phenomena, whose peculiarities can be better investigated, can be stripped at least of mystery, and referred to satisfactory mechanical principles, which alone are congenial to human reason and experience in the treatment of physical problems.

But, it may be said this is all mere theory. Exactly so. But is not a theory which meets those difficulties which are known, preferable to a host of conflicting theories which only seem to aim to obviate some special objection, and take no note of others? It would almost seem as if the well of knowledge had been pumped dry, so eager are the *quasi seekers after truth* to enter caveats, lest some pet idea should be patented by a more active prospector, and nothing be left for themselves. We regard a theory as a very good thing if held only provisionally until mellowed by time. And what is science now but a tissue of provisional theories? We might say (with some exceptions) of random guesses; but, nevertheless they are not tabooed, unless they come dangerously near solving some knotty points which have hitherto baffled the wise.

The *value* of a theory depends, alone, on its intrinsic ability to pioneer a way to the solution of any physical problem, and not on the reputation of the author. If our theory be estimated by that standard it will receive attention; but unfortunately this is not the rule. No greater name appears on the roll of science than that of Herschel, yet Sir William advocated the idea of a solid sun, in the face of its mean density being little more than that of sea water; and a temperature on that solid globe so very delightful as to constitute the most blissful abode for living beings in all the solar system; being shielded from the blazing furnace above by a perfectly reflective canopy, which we see as the penumbra of a spot, and which permits his solid surface being "*richly stored with inhabitants.*"

Sir John Herschel also, in speaking of the willow leaves of Nasmyth, argues, their definite shape and exact similarity one to another are "quite repugnant to the notion of their being of a vaporous, a cloudy, or a fluid nature," and, therefore "considers them as separate and independent sheets, flakes or scales, having some sort of so-

lidity." He evidently leans to the idea of these amazing objects of 1000 miles long by 200 or 300 miles in breadth being endued with life, for he says: "Looked at in this point of view (as the immediate sources of the solar light and heat) we cannot refuse to regard them as organisms of some peculiar and amazing kind; and though it would be too daring to speak of such organizations as partaking of the nature of life, yet we do know that vital action is competent to develop at once heat and light and electricity."

Surely our humble contribution to the general list of theories will not be deemed more extravagant than the above cited cases, legitimatized by the deservedly great name of Herschel.

CHAPTER III.

THE SOLAR CORONA.

We now come to a phenomenon acknowledged to be a great mystery—the corona of the sun—occasionally displayed in the transitory interval of darkness during a total eclipse. Nothing can be more awe-inspiring and grand in character than the contrast which nature presents by the sudden extinction of sun-light. At the beginning of totality, a single second is enough to plunge the face of nature, both earth and sky, into a bath of funereal gloom. No wonder it was regarded in more primitive times as the expression of an offended Deity, or as evidence of some terrible contest between the powers of nature. Even in our own day there is a disposition to seek society as darkness approaches, both in man and beast, and a still stronger disposition, at the end of totality, to hail the returning light with a shout of rejoicing; for it only requires another second to flood the scene with abundance of light, so powerful is the narrowest crescent of the sun's limb in mid heaven that it exceeds the light of the full moon a thousand times. During that brief interval of totality a spectacle is presented in the heavens which few have ever seen. There are only a few days of total obscuration of the sun by the moon in a century, and then only along narrow bands often not a hundred miles in width; so that the chances of any particular individual seeing the corona in a whole life-time are exceedingly slight, unless that individual purposely places himself at the time somewhere on the central line, and even then a passing cloud may render an expensive journey fruitless. They who have seen that spectacle will

ever remember the awful magnificence of the scene. The black moon is not thought of, the observer only recognizes a black *sun*, rendered doubly black by a glorious radiance surrounding it, while the inner ring in contact with the limb, for a height equal at least to one-sixth of the diameter of the central body, blazes out with an effulgence too bright to linger on. Above this, bright streamers, in bundles of irregular width and length, shoot out like the streamers of the northern lights, divided by distinct dark parallel lines. These start from the glowing ring below, and, at the longest, stretch out a full diameter with undiminished light, and still further with a gradually decreasing intensity, until they finally become lost in the sky beyond. This at least was the fact observed in 1869 at Des Moines in the State of Iowa, by the author, whose sole object was to portray the outlines of the corona, which he had long before maintained could not possibly present the well-defined circular halo as contended for by many. This opinion was brought to the notice of many of the most prominent physicists of the day in a circular sent them at least a month before the eclipse, to say nothing of the publication of his views in 1854; but no one ever called that fact to mind, although the published theory was verified in the fullest manner by the event. These general facts have been established by all the eclipses which have since occurred, and also by those previous eclipses which have been recorded sufficiently to give them importance. (Vide Appendix, note D.)

In the splendid volume of the "Memoirs of the Royal Astronomical Society for 1879, vol. xli.," we have a compilation of all that is known, by a general contribution of the observations of many who have labored in this interesting department of astronomy. From this and other sources we propose to draw such evidence as may be needed to establish certain postulates relating to the puzzling phenomenon presented by the corona, and other solar phenomena. In so designating it we merely echo

the views of such writers as Mr. Proctor and Professor Young, who have both issued elaborate treatises on all solar phenomena. Mr. Proctor, it is true, advances a theory of his own with apparent confidence, yet he acknowledges the corona to be a phenomenon difficult of interpretation, and which "remains even at the present day not clearly understood," while Professor Young confesses "that in view of the brief glimpse of the corona obtainable at long intervals, we must evidently wait awhile for the solution of the problem presented by the beautiful phenomenon," while it is something to know that it "is mainly solar, and that therefore it must rank in magnitude and importance with the most magnificent of natural objects, we have yet to find a satisfactory explanation of many of its most obvious features. It is certainly very complex—matter meteoric, and matter truly solar, orbital motion, solar attraction, atmospheric resistance, and actions thermal, electrical and magnetic, are probably all combined.

"At present it would seem that the most important and fundamental problems of solar physics which are now pressing for solution are these: First, a satisfactory explanation of the peculiar law of rotation of the sun's surface; second, an explanation of the periodicity of the spots, and their distribution; third, a determination of the variations in the amount of the solar radiation at different times and at different points upon its surface; and fourth, a satisfactory explanation of the relations of the gases and other matters above the photosphere to the sun itself—the problem of the corona and its prominences.

"One might name many others of hardly less interest, such as that which has to do with the intimate connection between terrestrial magnetism and the condition of the solar surface; but, on the whole, the four named seem to be those the solution of which would most advance our science. Not, of course, that we are to suppose that even their solution would bring us in sight of the end or limit

of knowledge. Each onward step only opens before us a new, wider, and more magnificent horizon, with infinity still beyond."

In this brief passage, Professor Young candidly sums up the conclusions which are generally accepted by the physicists and astronomers of the present day, with the exception of a few who happen to be the parents or sponsors of new or old theories. For himself, while disclaiming the name which science confers on her followers, the author, standing upon the broad platform of nature, refuses to accept such dicta for his guidance, and contends that the analogies, which all may read, are competent, when read aright, to divest solar physics of their most mysterious features; and it is to establish this truth that he has been induced to place upon record, the second time, this mechanical theory of the sun and planets, as stated in a previous chapter, although it may be branded by the élite of science as a speculation of "electric vortices, or any similar nonsense."

As it is now generally conceded that the corona is mainly solar in its origin, it would be a waste of time to examine or refute the opposite theories that it emanates from our own atmosphere or the moon. The moon, however, being now proved to be utterly bare of atmosphere, has no standing in such a cause, while Mr. Proctor, in his book on the sun, has completely disposed of the agency of the terrestrial atmosphere in originating the corona. He has called attention to the fact, that at the time of greatest obscuration, when the corona is best seen, our atmosphere, for many degrees around the sun, is deprived of all direct solar light, and, therefore, can produce no reflection, but, on the contrary, should present a dark circle of at least 23° in diameter immediately around the sun. The corona must, therefore, belong to the sun, and shine the more vividly on account of the absence of light in that part of the atmosphere through which it has to pass to the eye of the observer. But it does not therefore fol-

low that it is in the ordinary sense a solar atmosphere. There may be, and no doubt is, a very extensive gaseous envelope surrounding the sun, which may be considered variable, but permanent; but those long streamers sometimes traceable to a distance of 5° or 6° from the limb of the moon, as in 1878 by Professors Newcomb and Abbe, are utterly irreconcilable with the idea of an atmosphere, especially as the streamers were comparatively short in the direction of the poles.*

The same inequality was observed August 18th, 1868, as drawn by Capt. Bullock, on the island of Celebes, who states that "the whole outline of the corona was sharply defined: there was no indistinctness in any part of it." Governor P. Henessey, on the island of Borneo, describes the long branching rays as "more than twice the diameter of the sun, which his assistant, Lieut. Ray, called 'horse-tails.'" How an atmosphere of ponderable gas could assume such a shapeless outline as the drawing of this eclipse represents in the memoirs referred to, is beyond comprehension. Yet while such a theory may be utterly discarded as unworthy of consideration with respect to the upper portions of the corona, yet there may be, and very probably is, a very extensive shroud of incandescent gas reaching far above the chromosphere with

* In future eclipses it would be wise to enlist every suitable volunteer to observe, apart from others, with that best of instruments, the naked eye, instructing each one to attend to one thing only, and briefly record his impressions on diagrams prepared beforehand. If this had been done in 1869 and 1878 we might have had the testimony of a thousand educated men, who would have been glad to make themselves useful on such interesting occasions, and even in other countries than the United States. A similar plan on other occasions would have been productive of some valuable details, which the man of science, with his polariscopes, and spectroscopes, and cameras, was necessarily debarred from observing. Unfortunately, the unscientific are apt to regard observations made without instruments as of little value, which feeling is rather fostered than opposed by the initiated, as a useful barrier against any invasion of their special territory by all who cannot pronounce the shibboleth of the scientific dialect without lisping.

a moderately well-defined but variable and somewhat irregular margin, which constitutes that ring of dazzling whiteness above alluded to. As this inner corona—if it may be so called—gives a spectrum due to incandescent gas, and the long streamers for the most part give a continuous spectrum, it is safe to admit some sort of division between them and to designate them as the inner and outer corona; although the admission of such a voluminous appendage as the necessities of such a theory required involves difficulties almost equal to those it was devised to meet. In the case of the outer corona no such devices can be resorted to. It represents a case *sui generis*, and cannot be so easily disposed of. But no two eclipses present the same aspects. In 1869 Mr. Dixwell (vide U. S. C. S. Report, appendix 8, page 23), at Shelbyville, Kentucky, reports the corona as having "rays of very irregular length, the longest of which extended more than a diameter of the moon, and one observer thinks the maximum length one diameter and a half. Generally the rays radiated from the moon's centre, though there were some deflections. They were grouped in four great pencils or cones of irregular size connected by shorter rays forming together a continuous halo." In the same report Mr. R. D. Cutts, at Bristol, Tennessee, states, "The lower left hand quadrant appeared to be comparatively bare." (This point would be close to the sun's south pole.) Five and a half degrees to the westward, at Springfield, Illinois, Mr. R. McLeod, also of the U. S. C. S. party, says, "From the outer rim of the corona bright white rays emanated on every side, but their length was greatest in four directions. The four areas of rays were of unequal length, that in the south-east quadrant—the lower left hand quadrant of Mr. Cutts—being the longest." Prof. Pickering, at Mt. Pleasant, Iowa, as appears in the Journal of the Franklin Institute, describes the corona as "an irregular four-pointed star. Two of the rays were nearly vertical and two horizontal—the left hand one pointing

somewhat downward, while between it and the lower ray was a fifth smaller point." This does not tally with Mr. Chas. Schott's report, who was of the U. S. C. S. party at Springfield, Ill. In the Eclipse volume of the R. A. S., Mr. Meek's drawing of the corona is given, differing from the author's sketch drawn on the spot at Des Moines. Mr. Schott puts a feebler development of rays between the two principal bundles of rays on the eastern limb, or over the equator, whereas Prof. Pickering locates it between the eastern horizontal ray and the lower ray, which would be nearly due south. The two sketches will be found on pages 94 and 95 (Figs. 7 and 8). The difference of time between mid-totality at Des Moines and Springfield was about four minutes, or the shadow took that time to travel over the space between the two places, which is scarcely sufficient to account for any such discrepancies; for Prof. Pickering's account of its texture resembling the ragged edge of a thunder cloud or the crest of a wave torn by the wind, corresponded far better with the author's outlines than the tapering shafts or bundle of rays represented in Mr. Meek's drawing, as also the position of the fifth projection in the south-east quadrant. But in all well-observed eclipses this want of accord has been apparent. If we take the published pictures of the eclipse of 1878, we see there an enormous projection to the eastward, while other observers put the longest ray to the westward. This eclipse was also observed at Denver, Colorado. by Prof. J. N. Stockwell, of Cleveland, Ohio, whose carefully worded description is as follows: "I will now write you about the eclipse, and more particularly about the corona, which was the principal object of my attention. I am induced to describe it as if it consisted of two distinct parts. The first part I would liken to a luminous cloud of nearly uniform brilliancy, entirely surrounding the sun, and having a breadth of three-fourths of the sun's diameter. The light of this ring was the most intense at its base and slightly dimin-

ished in intensity as it extended outward from the sun. At the outer limit of the ring which I have mentioned, the intensity of the light diminished very rapidly, until it became invisible from its very faintness. I could discover no trace of structure in the ring to distinguish it from a homogeneous atmospheric envelop surrounding the sun.

"Outside of this ring of light of nearly uniform brightness, the corona exhibited a very marked contrast in its different parts. It extended to the *westward* in the plane of the ecliptic about three diameters of the sun, while to the north and south of the sun it did not exceed one diameter, while on the east side, in the ecliptic, its extent was about two diameters of the sun. These estimated distances include the breadth of the ring first described. The shape of these prolongations to the east and west was much like that of a fish-tail, and the intensity of the light might be compared to the thickness of the tail in its different parts. The prolongations of the corona in these directions seemed to be formed of rays of light resting on the cloud of light first described, but did not have the appearance of an emanation from the sun, because they were too nearly parallel throughout their whole extent to indicate an origin at the centre of the sun. In fact, if we suppose the central rays of these prolongations to pass through the sun's centre, the extreme rays were so nearly parallel to them that they would intersect the sun's limb at the distance of 70° on either side of the central rays."*

* During the spring of 1878 the author had requested Prof. Stockwell, as a personal favor, in case he went to Colorado to view the eclipse, to pay particular attention to the outline of the corona, having imparted to him the prominent features of his theory, and in fulfillment of that request he not only entered minutely into all he saw, but very kindly sent a sketch or drawing of the appearance of the corona seen in the clear sky of Colorado, which sketch appears on page 96 (Fig. 9) of this volume. The writer is also indebted to Prof. Stockwell for making certain computations at his request, which appear in columns 5 and 6 of Table III. That gentleman, however, is in no wise responsible for any part of the theory herein advanced or for the use made of the figures in the columns referred to, which are purposely kept separate in the table in order that they may be available

Prof. Stockwell's sketch of the corona does not at all resemble the drawing of Prof. Young, in which he combined the sketches of several observers with his own impressions. The discrepancy, however, is probably explained by the following, from his work: "In 1878, the writer, on comparing notes immediately after the eclipse with other members of his party, found that about half of them saw the corona principally extended to the east and west, while the other half, himself among them, were just as positive that it branched out mainly to the north and south. The photographs and other data, since collected, show that the principal extension was undoubtedly along the east and west line." (Vide "The Sun," page 215.)

Prof. Stockwell's sketch of the eclipse of 1878 is almost an exact duplicate, a little enlarged, of the drawing of the eclipse of 1867 by Herr L. Grosch, at Santiago in Chili, as delineated in the Eclipse volume of the R. A. S., and this resemblance is the more significant as occurring at a sun-spot minimum, which happened also in 1867. In both cases the pictures were mainly naked eye observations, which are decidedly superior (so far as getting a more correct outline of the corona) to any magnified image, inasmuch as it requires a smaller telescope than is usually employed to bring the whole corona into the field of

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for others who may desire to discuss the main question on which our theory hinges. The labor involved in the accurate determination of such details renders them as valuable as they are reliable, and to one engaged in such investigations, where facts and numbers are inexorably linked together, they will be appreciated. The drudgery of that tentative process which is often the only avenue of approach to nature's secret chambers, and, especially, in this particular and unique problem requiring incessant repetitions of the same process with varying elements, is wearing to the mind, and when the prospect is that such labor will only bring us to the vestibule of the temple we seek to enter, is a severe trial of the explorer's faith in a successful issue. When the reader fully understands the theory, he will then comprehend the irksomeness of that labor, which only by slow and successive steps has attained results worthy of confidence through an apparently hopeless series of approximations, which, at first, could only be regarded as bordering on probability.

view, besides losing much of the light from the extreme limits of the longest rays. Herr Grosch also testifies that the extent of the corona was much longer in the line of the sun's equator than in the direction of the poles. In fact, there is no conflicting testimony on this point except the combination drawing of Prof. Young in relation to the eclipse of 1878, which he himself afterward conceded was longest in the equatorial plane. Yet after all it can only be regarded as approximately exact.

The general fact that the corona is irregularly protuberant in the sun's equatorial regions, and depressed or deficient at the poles, does not imply that the longest groups of rays are at the equator. In certain years, as in 1715, 1766, 1842, 1853, 1867 and 1878, the ecliptic rays were much longer than the polar, but 1858, 1860, 1870, and 1871 the figure of the corona became more nearly square. Now it is remarkable that at the first set of dates the sun-spots were near their minimum, and at the last dates near the maximum. On the average, it is safe to say the general testimony shows a preponderance in favor of the equatorial plane. Yet there is a very great difference in the lengths of the shafts of light, the greatest extensions being at right angles, and lacking over 45° of coincidence with the axis of the sun.

On this point it may be remarked that the uncertainty about the orientation of both drawings and photographs of different eclipses, and the very different outlines of their most striking peculiarities, render it difficult to decide by what angle the great branches of the corona differ from symmetry with the axis of the sun. That there is a difference is generally agreed. That there is a marked symmetry also is testified by the majority of observers, and that the longest rays respect the equatorial plane of the sun rather than the poles is just as uniformly asserted. Now some of this want of harmony, where different eclipses are compared, may arise from the effects of perspective, and the different angles under

which the solar axis and equator are seen from the earth at different times of the year. In 1851 the corona was radiated, and the axis of the longest beam of light was inclined 50° from the sun's axis, with the sides concave outwards, as seen and drawn by Mr. Swan. In 1860 the rays were curved but concave inwards, and the axis of the groups inclined 45° to the sun's axis. Yet there must have been something to connect one side of the bands with the equator rather than the other side, although the angle was the same, or how could it be said that the light was "less intense in the neighborhood of the sun's northern as well as of the sun's southern pole?" In 1868 the observers at Burram Point, Borneo, saw bands of curved rays resembling horse-tails, and groups "at opposite ends of a solar diameter, which was inclined about 30° to the sun's axis." Yet at Masulipatam, 32° to the westward, taking all the observations together, the corona is represented as four principal groups of structure, whose axes made angles greater than 45° with the sun's axis.

These discrepancies are frequent, and how are they to be reconciled? May there not be an inherent tendency to rapid changes which will alone account for the wide margin of disagreement among observers of the same eclipse separated by 30° of longitude? Motions have been recorded, but from the brief time of totality and the many other features to be observed, it is hardly possible to note changes even on the most gigantic scale.

Now as this question of the angle which the axis of the corona makes with the axis of the sun is important, the author will here produce his own observations and experience during the eclipse of 1869, at Des Moines. He had taken with him an excellent five-inch achromatic (an equatorial with all necessary appliances), which he placed in position near the U. S. tent occupied by Profs. Harkness and Eastman, in order to obtain correct time. As totality approached, he unscrewed his darkening glass,

but replaced it loosely on finding that the thin crescent to which the sun was reduced would unfit his eyes for examining the corona. While momentarily expecting the extinction of the light, it nevertheless found him unprepared, as he had forgotten that he had again replaced the dark glass. Everything being therefore invisible, in despair he seized his finder, which he had before carefully focused and laid by his side; and thus alternately using the finder and his naked eye, he not only obtained a correct outline of the corona, but saw many features not noticed by others. Disregarding the fine protuberances scattered around the limb, he devoted his brief time to fixing the principal outlines with reference to the vertical, and as the finder had a terrestrial eye-piece, no confusion was caused by looking first with the eye and then with the telescope. The longest diagonal of the quadrilateral was N. E. and S. W., but measuring from the centres, if the N. E. extension of the masses of rays had been of the same length as the other three, the corona could have been included in a regular square figure whose diagonals would have been two diameters of the central body in length. The S. E. group showed distinct bands of curved rays. The striations were fine but plain, yet only the central striæ of the groups radiated. As groups, they were sensibly parallel where not curved. At the first glimpse of sunshine, in his eagerness to record what he had seen, he forgot to establish instrumentally the orientation of the diagram which he had previously prepared, and began immediately to fill in the chief objects of interest in their relations *inter se*, which he could distinctly remember having fixed in his mind's eye. This accomplished, he regarded the *contretemps* which befell him at the beginning as a happy accident; for with the lowest power of his large equatorial he could not have taken in more than about one-half of the whole corona. The figure which is given at page 95 is a faithful representation of the drawing then made,

and the only one which can recall to his mind the grand and vivid spectacle of the total eclipse of 1869.

In Mr. Proctor's work we have a copy of Mr. Gilman's colored drawing taken from the Washington observations; but it conveys no impression of verisimilitude to one who observed the same eclipse within a few minutes of the same time. Indeed, the editor of the Eclipse Volume of the R. A. S. remarks, that "Gilman's colored drawing, given as Plate XII. of the Washington observations, would seem to represent the appearance of the corona as seen by an observer whose eyes were dazzled;" and in a foot-note, observes that others have described similar appearances. But Mr. Gilman was too much occupied by the "rosy protuberances" to be very exact in the disposition and location of his dark bands, which are too numerous, too regular, and too extensive as compared with other drawings, he himself admitting the fact of "great exactness not being attainable in the few moments given to the observation." It is these dark bands or intervals on such an enormous scale, which gives form to the corona and constitute its chief mystery and inexplicability by any theory yet discussed.

Having lost the opportunity of determining positively the position of the axis through negligence, the author could only determine that the longest diagonal of the figure was nearer the solar equator than the poles.

It is singular that so few observers were mindful of the importance of locating the prominences of the corona with reference to the sun's axis, some leaving it uncertain from negligence or from ambiguity of language, while others, with an evident intention to leave nothing uncertain, neglect to mention whether their figures represented the corona as seen by direct vision or inverted, and if the latter, whether wholly, or only in part inverted. An erecting prism, or Herschelian eye-piece, when fixed on the meridian at noon, will represent a point in the limb of the sun in its true position in declination but not in right as-

cension. The vertex is then due north in all the middle latitudes north of the equator; but the eastern limb appears west and the western east. Now if the telescope inverts the image, and an object is described as seen in the N. W. quadrant, it is really seen in the S. E. quadrant; but if the image is erected as, in almost all solar eye-pieces, it is only half inverted, and its true locality is in the N. E. quadrant. Even the photographs of the eclipse of 1869, as well as of other eclipses, are somewhat defective in this respect, for want of care in connecting the vertex of the image with the axis of the sun. They, however, establish one fact which is probably reliable, that the coronal light around the sun is much less intense and also less extensive in the solar polar regions than in the intermediate spaces where the photographs show but slight differences in extent. It is no doubt the more intense light of the inner corona, which, mainly, gives form to the photographs, yet that ratio of intensity is probably an approximate measure of the ratio observed in the outer corona for the same eclipse. From the various sources available, then, we can, after all, only gather that the symmetry of the coronal rays with the solar axis is not quite exact, neither can it be affirmed that the corona is always concentric with the sun both as respects the inner and outer corona, as shown in various reports, drawings and photographs. The case of the eclipse of 1878 is emphatic on this point. In the eclipse of 1870 Mr. Brothers took five photographs at Syracuse, Sicily, all of which show the corona brightest on the west side (a very significant and valuable fact). In 1871, Capt. G. L. Tupman, at Jaffna, drew the corona with a decided extension of both the outer and inner corona to the westward, and in another skeleton sketch traced the outlines of the polar rifts or spaces deficient in light, with a very instructive commentary on them and on other special points of interest. In the eclipses of 1874 and 1875 the eastern side was smaller and less broken up into long rays than the western side

—according to the editor of the Eclipse Volume, R. A. S., page 716. But unfortunately Mr. Lockyer's report from Siam is not reconcilable with Mr. Ranyard's statement. The former reports "that the similarity in the corona as observed by us and by Mr. Stone just one year before is exceedingly curious. The drawings given by Mr. Stone, in so far as they agree amongst themselves, agree with the corona observed at Siam. This similarity does not merely extend to the symmetry about the sun, but also to the irregularities in this symmetry. Thus the nearly straight boundary lines of the corona which cut the axis at nearly right angles, are not quite parallel, but converge in both eclipses towards the east. The west side of the corona seems much more compact, the east side broken up into what the Siamese called fish-tails." How this can be reconciled with the remark of the editor of the Eclipse Volume we cannot see. His remarks are that, "The corona visible during this eclipse seems to have been similar in type to that observed during the eclipse of the previous year (for) on both occasions the eastern side of the corona was somewhat smaller and less broken up than the western side."

But does the corona change its shape under the eye of the observer?

Prof. Young in pronouncing on the superiority of the photographic method as a representation of facts and not a figment of the imagination, very justly adds: "This is not the case with the drawings; for it is remarkable how widely two consecutive artists will differ in their representation of the same object, seen by both with the same telescope, and under the same circumstances." While thus perhaps underrating direct observations, his opinion is not very decided against reports of rapid motion being seen; for he admits that "the corona does sometimes change perceptibly, even in the course of twenty minutes, while the shadow is traveling between stations only a few hundred miles apart. Some of the observers thought

they saw rapid movements in the streamers, and have described them as waving and flickering; one or two have even imagined that the corona whirled like a Catharine-wheel." Now let the reader, if he can, consult the volume from which these quotations are made and compare Prof. Plantamour's drawing of the corona of 1860 with Rumker's, or Secchi's, or Temple's sketch of the same eclipse, and he cannot escape the conviction that the corona is a perfect Proteus, justifying the response of one observer, who, when asked why he had not drawn the corona, curtly replied (if I remember me rightly), "How on earth could a man draw a thing which presented a different aspect every time you looked at it?"

In contrasting the eclipse of 1851 with that of 1860, the celebrated Russian astronomer, Otto Struve, remarks: "On that earlier occasion the corona was formed of an almost uniform dim light. Now, on the contrary, all the corona in the neighborhood of the moon's limb resembled a chaotic mass of clouds, which gave the impression that the whole mass of light was in an extraordinary state of agitation; besides the clouds, radial rays were predominant."

Preceding the eclipse of 1871, Mr. Lockyer had issued printed questions on this very point, and in answer to the injunction to "describe what has been unchanged throughout, and define its structure," it is stated: "Nothing appeared to have remained unchanged during the eclipse." Col. Tennant, who was in charge of the party sent out by the government of India to Dodabetta, "saw no changes in the corona—the rifts I was examining seemed perfectly steady," but he was engaged with the spectroscope. Capt. Morant, also, was instructed, and Col. Tennant reports that "he has furnished me with two sketches of the total phase, and notes answering the questions to be found in the instructions. Capt. Morant's sketches show very marked changes in the corona, but this hardly coincides with the account he gives. He says: 'There seemed a

considerable general change over the whole corona which made it difficult to draw its shape, but I observed no *marked* change of any kind. The rays in some places disappeared, and in others fresh ones came into view.'" The non-coincidence may arise from the difference of meaning which each attached to the word "marked." Where "rays disappeared, and others appeared" in other places under the eye, changes were sufficiently *marked*; but if the whole was changing, Capt. Morant probably meant that the changes in one part of the corona were not more marked than in other parts.

Mr. J. Bœsinger, at Ootacamund (Vide Eclipse Vol. R. A. S., page 692), says of this eclipse: "I observed that the shape or form of the corona, or glory which surrounded the eclipsed sun, underwent changes in form, even during the short space of two minutes; but you will easily see that an observer with no other means than an ordinary good telescope, his naked eye, and a photographic camera, was quite incompetent to draw any conclusion; suffice it, therefore, to say, that the changes in the shape of the corona during totality can but be compared to the slow transformations of forms in a dissolving view apparatus, or, perhaps more correctly, to the changes of form and shape we observe in isolated thin clouds."

These are a few of the facts we have selected as landmarks; but we might present a far greater array of witnesses on this question, if it would reconcile the differences which seem inseparable from it. This discrepancy arises from the peculiar nature of the phenomenon. Limited to a few seconds in any given locality when a total eclipse occurs; happening but rarely in the same localities, after the expiration of long intervals, and then perhaps traversing inhospitable deserts, both torrid and frigid, on the land, or confining its track altogether to the ocean (as during the present year), its observation is beset with more obstacles to an effectual study of its phases than any other natural phenomenon. The sum of our

knowledge is therefore small, and one of the most significant facts brought to light by the labors of those who have exercised themselves in its study, either as observers or writers, is the reality and irreconcilability of the differences we have noted, which makes it more than probable that the physical cause to which the corona owes its origin must have a wider range of action and influence than the recognized principles of physical science can at present suggest for its elucidation, and it, therefore, shows the necessity of a radical change in our conceptions of the forces to which all solar phenomena owe their origin.

CHAPTER IV.

THEORIES OF THE CORONA.

We are now prepared to define the problem of the corona by bringing together the facts which have been observed, with such inferences as have stood the test of rigid scrutiny; for if the facts are real, and the inferences just, any theory which claims ability to solve it, must leave neither fact nor inference unexplained.

We will begin our enumeration with those which may be regarded as having been most generally observed, and therefore considered the best established, and then examine the theories.

It is altogether foreign to our plan to array in order all that the telescope and spectroscope have revealed, or even the features gleaned by unaided vision. We have cited only a few cases to show the general drift; but the reader will find our generalizations in the summary we give below substantiated by the verdict of those whose names stand foremost in solar physics.

1. The corona is a real phenomenon pertaining to the sun and altogether independent of the earth and moon.

2. The corona is composed apparently of two portions, which are neither distinctly separated nor permanently united, for their relative diameters are different at different times, and their outlines are often unsymmetrical and non-concentric; but not always.

3. The general contour of the outermost portion is that of a quadrilateral, whose diagonals are inclined about 45° to the sun's axis—the two bodies being sensibly symmetrical.

4. The polar axis of the corona is shorter than the line

at right angles to it, taking that axis as approximately coincident with that of the sun, and therefore symmetrical with it.

5. The part of the corona nearest the sun is sometimes shown as a homogeneous band of light of great and uniform brilliancy, and sometimes of irregular masses of light crossed by straight and curved rays at all angles, as if produced by chaotic movements in a gaseous atmosphere.

6. The outer part of the corona is usually disposed in apparently independent groups, or bundles of shafts of light, finely, but distinctly striated, each bundle shooting outward usually in straight parallel lines, sometimes traceable several degrees from the limb. The striæ are also often curved in their outer part, especially near their bases, and frequently are of synclinal structure, and sometimes, but not always, radial.

7. The corona is often divided into pencils by dark wedge-shaped rifts reaching from its outer visible margin to within a few minutes of arc of the limb, and so far symmetrical that similar rifts and similar pencils are often observed diametrically opposite each other. This is especially found to be the case near the sun's poles, where two opposing rifts are usually observed.

8. The light of the corona is often observed brighter and more extensive on one side of the sun than on the other, and that want of symmetry between the centres requires as satisfactory an explanation as any other peculiarity, which is now looked upon as an undoubted fact.

9. The gaps and rifts of the outer corona are often found to correspond with depressions in the outline of the inner corona, and even with depressions in the chromosphere immediately below.

10. The axis of the zodiacal light—that pyramid of faint nebulosity which only comes fully into view at the end of twilight in the evening, and beginning of twilight in the morning,—also seems to respect the sun's equator.

It is therefore very reasonably considered as a solar appendage of a more diffuse and attenuated texture than the outer corona, as this last is as compared with the more stable material of the inner corona. Its vertex is sometimes seen 90° from the sun, and therefore reaches to the orbit of the earth with a base of 30°. Its visibility is, however, so much fainter than the corona that their connection escapes recognition during total eclipses; but no theory of the corona can possibly stand which does not refer the two phenomena to the same physical cause.

11. The corona has been often observed in rapid motion, but owing to its immense extent and distance, the brief time of visibility and the multiplicity of details suddenly presented to the observer, few have been able to give a definite opinion on the subject of coronal changes.

12. The light of the inner corona is found to give spectroscopic lines indicating its source to be incandescent gas (unless the interpretation of spectroscopic results are found to be erroneous by future discoverers) and these lines are found to be as strong in the middle of a dark rift as anywhere else. (See Young's "Sun," page 232.)

13. The light from the outer corona has been found polarized in a plane passing through the sun, showing a considerable portion of reflected light, while at the same time the spectroscope has shown in the lower portions (although but dimly) the bright lines which belong to incandescent gas, and a continuous spectrum in its rays and streamers.

14. The corona is analogous in many respects to the aurora of the earth, and this similarity cannot be ignored in any general theory of its origin.

15. The greatest disproportion between the polar and equatorial diameters of the corona seem connected with the solar spots. At the spot minimum epoch the ratio of the diameters of the circumscribing ellipse has been observed as two to one, as in 1867 and 1878. At other times as three to two; while at, or near, the spot maxi-

mum epoch, they are often not more than seven to six. 1860 and 1870 were eclipses of this latter class. This fact must also be accounted for to entitle a theory to our respect or confidence.

16. Considering the jet prominences as part of the corona, it has been ascertained that in elevation and frequency they excel in the spot zones of latitude, and are less at the equator, although greater there than at the poles, where they are seldom or never seen.

Up to this time no theory has been advanced which will account for even one of the above conditions without coming into collision with the fundamental principles of dynamics, yet we contend that a true theory of the corona must be held responsible for every one of them.

Before testing our theory by its competency to expound the facts concerning the corona which we have gleaned from our brief survey of this interesting field, we will only give a passing glance at some other theories; for every one who has labored in that field may be credited with suggestions and speculations having more or less claims to respectful consideration. But we will limit our survey to the meteoric and emission theories of the corona. Mr. Proctor, whose work we have already quoted, is the chief advocate for these theories. This gentleman has expanded the meteoric theory of the zodiacal light of Sir John Herschel, who, however, rather insinuated than proposed it.

As that theory is based, primarily, on the vast numbers of meteors circulating through the solar system and on the necessary corollary, that their numbers in a given space must increase in an inverse ratio of the distance from the sun, as exemplified by the planets themselves; and that the reflection by them of the solar light would not only account for the corona, but also for the zodiacal light, which seems from many points of view to be a kindred phenomenon. Now there is, against this theory,

the very grave objection that it throws a dim light, only, on three of our propositions, 1, 4, and 10, and is utterly irreconcilable with the majority of the remainder. Foreseeing that there were features in the corona, such as the long dark rifts or shafts of comparative faintness shooting out to many degrees beyond the margin of the central body which the meteoric theory could not be reconciled with, he says: "The meteoric theory will account for a radial dark bar, as an occasional phenomenon. But that such bars should be a characteristic phenomenon of the corona, or, that in any single case the corona should be seen streaked with several such bars, is a phenomenon which nothing in the meteoric theory considered *per se* is calculated to explain." He therefore very prudently drops another anchor, which he calls an emission theory, not, however, to be regarded as intended to displace the meteoric theory, which "as accounting for *some* slight part, at least, of the coronal light, can scarcely but be regarded as demonstrated." He says, "Furthermore the meteoric theory advocated above—a theory quite distinct from that of a meteor generating emission—need by no means be abandoned, if the emission theory is regarded as established. It will remain for future observations to determine what proportion of the coronal light is due to the several causes here considered."

A very little reflection will show the reader to what irrational lengths the scientific world has been driven, when such a theory as this emission theory is so spoken of. Mr. Proctor thus propounds the theory: "*A portion* of the coronal light is due to the ejection of matter from the sun, and either chiefly, or wholly, from those bands of the solar surface which we have thus far termed the spot zones." Feeling that the almost incredible velocity of 300 miles per second, which would be required to eject matter even in vacuo to the observed limits of the corona, is perhaps overdrawing his account at the bank of public confidence, and that even that velocity is not sufficient

when the matter to be ejected must necessarily be in the state of vapor, and have to pass through a gaseous atmosphere of *great density* if its height is anywhere near the figures at which it is at present estimated, he seeks support for the theory in the velocities observed in the formation of jet prominences, which to reach the height at which they have been observed, must have an initial velocity of at least 300 miles per second. "So that" (as he says) "it cannot but be regarded as probable (though it may be perfectly inexplicable) that the glowing hydrogen of the jet prominences is ejected with a velocity many times exceeding that which would be necessary to carry matter away from the sun, if he were not surrounded by an atmosphere. Now since other matter is ejected along with the hydrogen, and some of this other matter is certainly denser than hydrogen under equal circumstances of pressure and temperature, we cannot but believe that such matter undergoes far less retardation than the hydrogen, in passing through the solar atmosphere." And hence he concludes, "that the matter of the smallest jet prominence actually recognizable as such, must have been ejected with a velocity sufficient (if there were no atmosphere) to carry the matter forever away from the sun." Thus the way being prepared, he arrives by easy stages at the conclusion, that aërolitic masses are thus projected from the sun, as such masses actually fall to the earth in greater numbers by day (according to Humboldt, Herschel, Heis, and others) than by night, and it is at noon, when the sun is on the meridian, that the earth is best placed for receiving such solar visitants.

This *seems* like a solid fact; but its apparent solidity is derived from another fact of still greater solidity, *Sol regit diem, noctem Morpheus gubernat*, which must have occurred, also, to himself, although silently passed over.

The jet prominences range, according to Zöllner, from 30 to 120 seconds, or from 54,000 (*sic*) to 140,000 miles. According to Young (who is perhaps the best authority),

from 20,000 to 30,000 miles. But this refers to the quiescent order. Of the eruptive class, Secchi records one which attained the enormous distance of 300,000 miles from the edge of the visible disk of the sun, and Young, one of 350,000 miles. The velocity of such motions is calculated to exceed 100 miles per second, and sometimes, though very rarely, 200 miles.

The spectroscopic department necessarily requires much practice, and many costly appliances, besides exacting time and labor few can spare for persevering attention, and the subject of the prominences is only here introduced to direct the reader's attention to a few facts, concerning which there is little doubt; but which are so connected with the corona as to entitle them to claim as full an explanation as any other feature of the phenomenon. Hence this low velocity of projection, which Mr. Proctor cites on the authority of those who have paid the necessary attention, needs explanation.

The necessary velocity computed by Mr. Proctor to carry matter so far as 300,000 or 350,000 miles against the central attraction, was 255 miles per second; but he infers, from the resistance it would meet with, that "the ejectorial velocity exceeded enormously—exceeded *many times*—the utterly inconceivable velocity of 255 miles per second." To meet the requirements, then, of Mr. Proctor's theory, a velocity of four times greater would perhaps suffice, but a thousand miles in a second exceeds every known or computed motion in astronomy. The famous comet of 1843 had a less velocity than even 400 miles per second in making its sublime perihelion passage, and 400 miles per second even at the surface would carry matter forever away from the sun.

Such a theory inevitably contradicts itself. If there be a resisting atmosphere at an elevation of even 200,000 miles above the photosphere, what is its density? If that density be infinitesimally small, so is its resisting energy. If appreciable, what is its density at the surface of the

sun, with a central force 28 times greater than on the surface of the earth? Our atmosphere, 3½ miles above the surface, is reduced in density to one-half of what it is at the surface. Another 3½ miles reduces it to one-fourth, and so on, until at 45 or 50 miles its existence becomes mythical.

Now, taking the expansion of gases by increase of temperature as actually proved by experiment, and calculating the temperature of the solar atmosphere from such data as we possess, and taking the height of the solar atmosphere at 200,000 miles, we get a surface density at least 100 times greater than is compatible with the most reliable teachings of the spectroscope, which gives a pressure of about one pound to the square inch. Now, which shall we believe?

But it may be said, these velocities are actually observed and measured. Granted; but it does not follow that the sun has such an extensive atmosphere because it is surrounded by a corona. It does not follow that these prominences are all due to eruptive forces indicative of a pressure in the interior of the sun analogous to the steam in our high-pressure boilers, else we might look for some uncommon concatenation of circumstances—an accidental stoppage of the vents—from which cause an explosion might ensue which would rend the superficial crust (if crust there be) and fill the solar system with its molten matter, and leave the sun a wreck, thus curtailing the usual supply of light and heat necessary for the well-being of the planets, and bringing the history of their living occupants to a disastrous close, even if they escaped the flood of meteoric fire which such an explosion would scatter broadcast throughout the system. Neither does it follow that velocities measured by the refined methods of modern astronomy are so much in error as to require to be quadrupled in order to bring them up to the computed velocity of projectiles. Nor does it follow that the erupted matter comes from the sun, either from the photo-

sphere, or from a lower level. Our theory gives a very different explanation of these prominences, reconciling the absence of eruptive prominences in the polar regions with their frequency in lower latitudes, which Padre Secchi has confirmed completely; for he has seen in other regions, clouds, analogous to terrestrial clouds, unconnected with the chromosphere; and Prof. Young frankly supports this view by citing a similar observation of his own made October 13, 1880: "A small, bright cloud appeared on that day about 11 A. M. at an elevation of 2½′ (67,500 miles) above the limb of the sun (he does not say in what solar latitude this occurred) without any evident cause, or any visible connection with the chromosphere below. It grew rapidly, without any sensible rising or falling, and in an hour developed into a long stratiform cloud irregular on the upper surface, but nearly flat beneath. From this lower surface pendent filaments grew out, and, by the middle of the afternoon, the object had become one of the ordinary stemmed prominences."

We have here a very obvious analogy between solar and terrestrial clouds. The great cumuli, under whose base the storm is raging, has a flat surface beneath, but its upper surface shows irregular piles of grotesque form, of sudden origin and transient outline, which, after a few hours, settle down into a regular stratus and gradually disappear. Here we have a useful lesson, and, in fact, if we would follow more the teachings of Nature as exemplified in our own little world, we would be better able to interpret what is doing in other worlds; for the same general design is apparent in all, and the same laws operate to accomplish that design. This principle has been kept in view from the first inception of our theory, and, if we have succeeded in linking so many phenomena to one common cause, it is owing to our faith in that principle. The fact of filaments forming and proceeding from the under sides of such clouds and growing in length downward for about three hours, very much weakens

the eruptive and emission theories, and suggests the possibility of some of the cited cases of eruption having been misinterpreted, or unintentionally exaggerated.

The spectroscope is a wonderful instrument, and its revelations may all be, to *a certain extent*, reliable; but some of them may be justly suspected of uncertainty. Yet, it may be considered sheer presumption for those who are not spectroscopists to question any of the dicta uttered by those who are. *Festina lente* is a good old saw, and the author has exemplified his faith in it, by waiting for thirty years before publicly calling the world's attention, a second time, to a theory which, if true and accepted, would enlist a host of observers, through whose labors millions might be saved annually. As long as there are differences of views and opinions on special points, the language of the spectroscope is in a great measure an unknown tongue, and but few can understand it. Feeling well fortified in his position, the author clings to the idea that the spectroscope has not proved that the matter of what are called eruptive prominences comes from the body of the sun, and that further observations are needed to establish this as a fact. His theory refers these eruptive jets to local disturbances beneath the chromosphere, and their rapid and fantastic movements to another cause than the bursting forth of gases through volcanic vents as exploded gunpowder driving projectiles before them. What is driven upward are webs of gossamer rendered visible by excessive reduplication.

It is not uncommon for the long flat prominences to cover 10° of the solar limb; but this is equal to 76,000 miles, nearly, and there is no reason why the extension in the line of sight should not average the extension at right angles. If these strata of cloud were not of the flimsiest kind, such wide patches ought to be visible on the photosphere of the middle of the disk; but as the veil caused by such interpositions is not seen, it is fair

to infer that its visibility on the limb is only due to the great extent of the cloud measured along that visual ray; for if we take the depth of the chromosphere as 10″, say 5,000 miles, and consider that cloud as but a part of the chromosphere, we have a line = 2 × 66,070 = 132,140 miles in length, or, allowing for the concavity, 100,000 miles of such matter or gas as the cloud is composed of, to render it visible. And we know not how much the eruptive jets may be exaggerated in apparent height and velocity by the same effect of reduplication. Taking the top of some recorded prominences as 300,000 miles above the photosphere, a line from the eye to that top would be tangent to the limb if 592,000 miles long, equal the tangent of 36°, which, reckoned both ways from the point of tangency, amounts to almost a whole quadrant of the sun's circumference. Now, floating clouds invisible when isolated, might, when accidentally placed in line, start into visibility, remain so a few minutes, change shape rapidly, and then vanish as if they had never been.

In alluding to a possibility, we do not intend to question the facts observed; we only say, that it does not follow, even if such sudden elevations of visible gases are observed of the magnitude claimed, that these are eruptions from the body of the sun, which we contend has never lost a pound of his substance since he became a sun. It is contrary to every assured principle of solar physics. Matter has, no doubt, fallen into the sun, and it is conceivable that even comets occasionally fall into the sun; but it is inconceivable how matter could ever leave it when once a part of the solar substance, unless from a colliding body of great mass striking with cometary velocity.

A theory is not tenable which resorts to solid metallic bodies like some of our aërolites, thus propelled from the sun so constantly as to account for the permanence of the corona. But Mr. Proctor says, "It can scarcely be doubted that, exceptionally perhaps, or perhaps not un-

commonly, matter *is* projected as far as the Earth's orbit, or even beyond. One would even expect that no inconsiderable proportion of the *sun's substance* [the italics are not in the original] might be ejected with such velocity as to pass forever away from his dominion" (see Proctor's "Sun," page 420).

The essential feature of Mr. Proctor's emission theory is, that the assigned cause conflicts with all we know of solar dynamics. It may be thus briefly stated: Eruptions on the surface of the sun project solid material bodies (or bodies which on cooling become solid) into orbits which, even if projected obliquely, could only make one revolution without falling again on the solar surface unless they were projected with a velocity great enough to escape the sun's "dominion," in which case they could not account for the "permanence of the corona," unless the normal business of the sun is to dissipate his substance like a prodigal son indifferent as to consequences. But how would this comport with the *greatest* of all questions of Solar physics; from what source does he draw his supplies of light and heat? We are aware that Mr. Proctor and many others look for the *final* extinction of the sun and of all other stars; but there is another school which looks forward with hope, and sees, in the *fall* of meteoric masses into the sun, a store of kinetic energy in the infinite *Outside*, which promises it a perpetual existence with undiminished light and heat. Of this school Sir Wm. Thompson is the reputed father. Now which theory must go to the wall? (*See* Appendix, Note *E.*)

If that insuperable objection mentioned above could be removed, Mr. Proctor's theory might account for a normal condition of permanency, by showing that the unavoidable collisions and consequent precipitations of the colliding bodies to the sun, were in number equal to the number of ejections, thus restoring to the sun the kinetic energy it might be supposed to lose by the projection of so many bodies from his surface. But that one fatal ob-

jection cannot be surmounted. And by his own showing the measured velocities are insufficient, and therefore he suggests, "That it cannot but be regarded as probable (though it may be perfectly inexplicable) that the glowing hydrogen of the jet prominences is ejected with a velocity *many times* exceeding that which would be necessary to carry matter altogether away from the sun, if he were not surrounded by an atmosphere."

As Mr. Proctor's theory of the corona at its different elongations has received more elaborate garnishing than any yet propounded, we have selected it as a sample of the straits to which physicists of acknowledged reputation are driven by the complicated phenomena they seek to explain. But we take pleasure in referring the reader who wishes thoroughly to understand the magnitude and importance of the many physical problems presented by the sun, to Mr. Proctor's book, as he has succeeded, wonderfully, in treating the most abstruse questions in a pleasant popular vein, without lowering the standard of scientific precision. But in the attempt to refer too many facts to the same cause he has often to qualify assertions which have been previously made respecting them as unanswerable. That we have not misstated his views we again quote his own language on page 417:

"Now since other matter is ejected along with the hydrogen, and some of this other matter is certainly denser than hydrogen under equal circumstances of pressure, we cannot but believe that such matter undergoes far less retardation than the hydrogen in passing through the solar atmosphere. How much less we cannot say, but it seems no rash assumption to suppose that the metallic vapors (*a fortiori* if they condensed into metallic globules) would retain a velocity sufficient to carry them even beyond the observed limits of the corona." To this he adds (page 419): "Now, when we remember what the spectroscope has taught us respecting the constitution of the corona, we cannot but see that the inference deducible

from the preceding reasoning—the inference namely, that erupted metallic vapors pass away to a far greater distance than the erupted hydrogen—is very much strengthened." Mr. Proctor's summing up of his views in 1870 (which it is but fair to give in his own words) it is to be presumed, expressed his views when the last edition of his work on the Sun was published; as in referring to them (p. 390) he says distinctly, "I do not find that any of the conclusions enforced above require to be abandoned, or even modified, in consequence of later observations." In justice to Mr. Proctor, however, we insert the summary above alluded to. (See page 388 of Proctor's "Sun.") "While the exact nature of the corona remains—and perhaps may long remain—a mystery, I know of few instances in which the general nature of a phenomenon has seemed more satisfactorily exhibited than in the case of the corona and zodiacal light. We have the strongest negative evidence against all other theories but one, and that one theory is confirmed by line after line of positive reasoning. To doubt what general view we should form of the corona and zodiacal light under these circumstances seems to me to savor—*not* of that wise caution which prevents the true philosopher from overlooking difficulties, but rather—of an inaptitude to estimate the value of evidence. As to details we may be doubtful. Other matter than meteoric or cometic matter may well be in question; other modes of producing light, save heat, electricity, or direct illumination, may be in operation in this case; and, lastly, there may be other forces at work than the attractive influence of solar gravity or the form of repulsive force evidenced by the phenomena of comets. As regards also the true shape and position of the coronal and zodiacal appendage—and yet more as regards its variations in shape—we may still have much to learn. But of the general fact that the corona and zodiacal light form a solar appendage of amazing extent and importance, that they are not

merely terrestrial phenomena but worthy of all the attention astronomers and physicists can direct to them, it seems to me that no reasonable doubts can any longer be entertained." May it not also be said that the corona MAY be an illusion?

CHAPTER V.

OUR THEORY OF THE CORONA.

In our preliminary chapter treating of the motions and density of the ethereal medium, we have shown that the centrifugal force of rotation of the interplanetary medium by rarefying the central parts of the solar system, begets an outward current along the equatorial plane, and an inward current of restoration down the poles of the solar vortex. But while this vortex motion of the ethereal medium is the mainspring of the vast machinery of our system, it is not literally true that the rarefaction begins at the axis of rotation. Ether, like other material fluids, is compressible as well as expansible by force. The polar currents arrive at the sun with the normal density of the outside spaces from opposite directions, and the immediate effect is condensation with enormous evolution of caloric in a perfect chaos of intermingling streams of electricity. This nucleus of greatest density is, however, limited in extent, and it is only from its outer surface (if the term can be applied) where the law of rarefaction by rotation begins—that surface being estimated at from four to eight millions of miles from the axis. But there is another feature of the system which requires a little amplification, before applying our principles to the case in hand. In the terra-lunar vortex, we have shown in the commencement, the inevitable result of placing two bodies in a fluid vortex is eccentricity of both bodies as regards the centre of motion. To constitute a perfect balance, which the laws of motion will exact, the centre of gravity of both bodies is the point which must occupy the axis of the rotating fluid, and hence, the earth's centre

at the moon's mean distance is $\frac{1}{85}$ of 238,390 miles, or 2,800 miles from that axis.

The same rule is observed in the solar vortex. Disregarding the planets, Mercury, Venus, Earth, and Mars, the action of the four great planets in displacing the sun amounts to nearly a million of miles if all these planets occupied the same helio-centric longitude. But this can never be except in a period reckoned by millions of years. It is an ever varying quantity as the planets revolve in their orbits, and goes through its changes from maximum to minimum, and from minimum to maximum, in about twelve years—owing to the great mass of Jupiter, which, if there be no planets exterior to Neptune, is supreme in determining the longitude of the centre of gravity of the system, and the amount of the sun's displacement. In citing an error from Sir John Herschel's "Outlines," where it is stated that the centre of gravity is always within the body of the sun, it is only for the purpose of showing how a palpable fact like the displacement of that body from the centre of the system, has been considered of so little importance as to be unworthy of being referred to with precision. In almost all other details Sir John Herschel has shown himself as precise as he was profound.

The period of Jupiter is 4,333 days, or 11.86 years, and the synodical period of Jupiter and Saturn is 7,253.4 days, equal to 19.86 years. Now five periods of Jupiter are nearly equal to three such synodical periods, therefore, on the average, every twelve years the sun is swung around by Jupiter alone, or by Jupiter and Saturn jointly, for there would be but a slight preponderance in the combined action of Saturn, Uranus and Neptune as against Jupiter, if all three were to be united in the same helio-centric longitude. Such a conjunction has never yet occurred in the past of historical time, and will not in the moderately distant future; yet this average, which only exceeds the period of Jupiter by a few days, has an un-

mistakable significance, in view of its near correspondence with the period assigned by Doct. R. Wolf, of Zurich, of 11.11 years for the solar spots.

But our present business is to render a good account of the difficulties presented by the solar corona, and we must beg the reader to accept this period as provisionally correct, until we come to elucidate the question of the periodicity of the solar spots, when we shall present the evidence of a better correspondence.

We see, then, in the corona, an effect produced by the incessant displacement of the sun from the axis of a stupendous vortex of ethereal matter, which is ever rushing down the poles to fill up the rarefied space of the interior. The centrifugal tendency of every particle of the medium is measured at different distances by the centrifugal force of the planets, but in the case of the ether there is no central attraction to restrain this centrifugal tendency. Each cylindrical layer is urged outward by its own motion and impelled by the layers behind, and getting more dense the further it is removed from the axis. But it is not condensation which causes a difference of density, it is the rarefaction which causes the difference, a distinction of prime importance to the theory. Now what may be the dimensions of the solar vortex, and whether we shall ever be able to obtain the data necessary for computing it are equally problematical. But great rarefaction, such as the inverse ratio of the square roots of the distances implies, indicates an overwhelming extent, both axially and equatorially, and we need not be diffident in claiming a very wide margin in this direction. It is calculated that our nearest stellar neighbor, α Centauri, which is over 200,000 times the distance of the earth from the sun, must feel the influence of his attraction; and if that is not counteracted by the attraction of other bodies in opposite directions, that it must describe an orbit around the sun in a period of sixty or seventy millions of years, dependent on the eccentricity of the

orbit. Ten millions of years, however, is a trifling matter in such a calculation. But it justifies the moderate hypothesis that the solar vortex *may* extend to half the distance of α Centauri, and, therefore, we shall have a sufficient source of molar power to do all the grinding needed in the solar system. But if this be doubted, can we not justly fall back on that convenient auxiliary verb may?

From what do we infer the *density* or inertia of the ethereal medium? Are the laws of ponderable matter applicable to imponderables? Analogy and reason would answer yes; but for all that, the density or inertia of the ethereal medium *may* be greater than what we infer from its inappreciable effects in resisting the planets, which are no guide at all, if, as we hold, there be no difference in the velocity with which ether and planets revolve at equal distances from the sun, except, perhaps, from eccentricity of orbit.

Thus having prepared the way for the task before us, although such summary treatment is not calculated to familiarize the reader with the theory in full; yet we hope enough has been said to give him an inkling of the route to be pursued, and of the instruments to be pressed into the service, in divesting the solar corona and kindred phenomena of the mystery with which they have been charged.

In considering the various aspects under which we have represented the corona, we may summarily acquit No. 1 of all complicity with the earth or with the moon, and set the corona down without proof as a veritable appendage to the sun.

Secondly, There is no doubt a lower, denser, and brighter stratum of the corona apparently based upon the chromosphere, which is, nevertheless, very fluctuating and variable, with very irregular outline and sometimes divided by dark rays or rifts to its very base. This feature is fatal to any theory of a real gaseous atmosphere;

and although we recognize a difference, sufficient to justify the terms outer and inner corona, yet we regard them as essentially the same and due to the same physical cause. That cause we will now proceed to develop. Whatever the ethereal medium may lack in density or inertia is amply made up by velocity, as is exemplified in every thunderstorm; for, however much there is to learn, let it be fearlessly proclaimed that the inter-stellar ethereal medium "is neither more nor less than the electric fluid —the mighty energizing principle of space, the source of all motion, the cause of light, heat, of the aurora, the lightning, the zodiacal light, of the tails and nebulosities of comets, of the great currents of our atmosphere, of the samiel, the hurricane, and the earthquake." (See "Mechanical Theory of Storms," page 38.) And this we have contended for for the last forty years. During that time many who were not born when these views were first put forth, now claim with inflated assurance to have been first in the field, and generously ignore the source from whence their inspirations were drawn. If the author abandons for this once his usual indifference it is only to ask the caviller whether the science of the present day does not teem with conflicting claims of the most flimsy texture; claims which, if true, can add nothing to reputation, equivalent to the stigma of having contended for a straw?

But we shall not take up these several questions *seriatim*, which would be prolix and tedious, but rather exhibit them collectively, or as much so as possible, with due regard to the relative importance of each.

In the table (No. IV.) at the end of this volume, the reader will find the true radius vector of the sun on the first of January of each year, in units of the sun's radius, in the columns headed RR'. In the preceding columns he will find under the letters VV', the true helio-centric longitude of the centre of gravity of the solar system for over one hundred years—taking the centre of the sun as

the origin in both cases. In these tables the true anomalies of the large planets have been computed, and in the cases of Jupiter and Saturn, their long inequality has been determined and allowed for. Now let the reader understand that our arguments are based on the unquestionable accuracy of those figures, computed with the latest and most approved values of the masses and distances of the planets, and of the solar parallax from which they are derived.

What may be considered hypothetical stands on its own merit, and cannot vitiate the result obtained from elements which are acknowledged and esteemed by astronomers throughout the world, inasmuch as it is kept separate and distinct.

We have already taken our position on the gaseous constitution of the sun; that its heat is unapproachable by any human appliances, and simply inconceivable; that with such a tremendous temperature all known solids and liquids must be vaporized. It cannot be otherwise but that its outer layers must be regarded as its true atmosphere or photosphere. What is above this is hydrogen and vapors of transient visibility carried up with the hydrogen, which settle down again to the surface of the photosphere from whence they came. These last constitute the chromosphere, which would, under ordinary circumstances, be a very shallow stratum of hydrogen and other gases; but when expanded by heat and by other forces into a volume perhaps a hundred times greater in depth than what it would occupy as a terrestrial atmosphere, it shows as visible cloud by reduplications of very attenuated masses of gas, withheld from total dissipation by a natural viscosity due to elevated temperature. There is no doubt a limit to the repulsion of gaseous molecules, else our own atmosphere would expand and diffuse itself until some of it finally reached the moon; but no planet could long retain its atmosphere unless there were such a limit to its expansion.

These masses of vapors and incandescent hydrogen are not, however, shot out of solar volcanoes, like projectiles out of a Krupp or Armstrong gun, they are carried up far more effectually and with greater velocity by another force.

The sun, like the earth, is permeable to the electric or ethereal fluid. Suppose the great planets are so arranged that the centre of the sun is displaced by a whole radius from the axis of the vortex; the side of the sun nearest the axis is slowly rotating at the rate of one revolution in 25 or 26 days, and suppose the law of density, which has been deduced, prevails to the very centre of the system, that nearest side of the sun then becomes permeated—saturated—with an influx of ethereal matter of the density due to that distance from the centre. In 12 or 13 days the rotation of the sun has carried that portion of its surface to a distance of 800,000 miles more remote. The electricity (or if preferred the tension) of the ether, with which that side of the sun became permeated, finds itself too positive for its new conditions, and an escape becomes unavoidable, carrying with it, in its passage through the attenuated hydrogen atmosphere, some portion of it by what the schools call electrical convection. Now let us reflect that this process is not continuous in the same solar longitude; the electric tides ebb and flow as other tides; but there are times in particular localities when the escape of electricity, in the way pointed out, may expand a stratum of hydrogen of only two or three inches of barometric pressure, into a layer of 10,000 miles in depth, without creating any difficulty, arising from the great gravitating force on the surface of the sun, which is more than 28 times greater than at the surface of our own atmosphere. In such a case the gas will be of extreme tenuity, so much so that it will not at that elevation ever be seen as a spherical figure, but as piles and cloudy heaps in localities where the escape of ether is most violent.

Taking the outer boundary of this fragmentary and *etherealized* hydrogen atmosphere as the limit of the inner corona, it is obvious from what precedes that that limit must be very variable, and so it has been recorded on several occasions, that not only the inner corona, but the whole corona becomes eccentric, or more developed on one side than on another, and *at the same time.* Unfortunately, total solar eclipses are too few in number and too brief in duration to be readily appealed to, and we must be content with such records as we possess. But in all the cases wherever these facts are noted we find confirmation of the truth of our theory and no contradictions.

As an example we will take three eclipses noted for a certain correspondence between some peculiar phases observed, and the fact that these years were years of minimum sun spots. These are the eclipses of 1842, 1867 and 1878. In Table I. will be found Dr. R. Wolf's sun spot numbers, and, although the table was published before 1878, yet in No. 2299, p. 295 of the Astronomisch Nachrichten, Dr. Wolf has given 1878.9 as a minimum sun spot year; giving the period between the minima 1867.2 and 1878.9 as 11.7 years. In the table we find 1843 was a minimum year. Now it is considered a very *remarkable circumstance* that these three eclipses, resembling each other in the great extension of the equatorial projections as compared with the polar, should have happened on three minimum years (the difference in Wolf's numbers for 1842 and 1843 is slight). And, in fact, if we submit the coincidence to the test of probability (and this is the only reason science can show for attaching importance to it), we have a powerful argument for believing the two phenomena are connected.

As minimum spot years only occur once in eleven years (on the average), the chances are, of course, 11 to 1 against one such eclipse coinciding in time, even if a total eclipse happened every year. But there would be 100

chances to 1 against three such coincidences happening in three consecutive 11 year periods. This should be borne in mind, as we shall submit a case where the chances will be shown to be one hundred millions to one that our theory is a true interpretation of nature. But really there is nothing *remarkable* in this uniformity of causation. If the reader will turn to our table, he can take out the following details, which we will place in order—the earth's longitude being known.

Total Solar Eclipse.	Helio. Long. of Earth	Helio. *Long. of Centre.	Angle E. or W. of Sun.	Longest rays E. or W. of Sun	In Sun's Radii and in Miles.	Greatest Extent.
1842 July 7th.	285°	240°	45° E.	East.	1.5469 673000	Equator East.
1867 August 29th.	330°	150°	0°	Concentric.	.3404 150000	Equator Central.
1878 July 29th.	306°	50°	104° W.	West.	.5397 234000	Equator West.

*Long. of centre, signifies the longitude of the centre of gravity of the solar system.

As the numbers in the table are calculated for Jan. 1st of each year, a little allowance has been made for the excess in time, taking the nearest degree as sufficiently exact to illustrate the application. From the theory it follows, that when the centre of gravity is placed eccentrically as respects the sun, and the longitude of the earth is such as to differ from the longitude of the centre by an angle not much greater or not much less than 90,° and the distance from the sun's centre is considerable, that, then, the corona is also eccentric, and is greatest on the side of the sun where the centre of gravity is located.

Now in the case of the eclipse of 1842 the difference in helio-centric longitude was 45°, placing the centre of gravity on the east side of the sun at a distance of 673000 miles. The principal observer of this eclipse was Capt.

Biela at Padua, who reported that the corona extended to a great distance from the sun's limb in the eastern equatorial regions; and although he mentions that others saw projections on the western side also, the impression is, decidedly, that the eastern limb exceeded the western in conspicuousness.

The longitude of the earth, August 29th, 1867, was 330°, and that of the centre 150°—difference 180°—therefore, in this case (especially as the centre of the sun was nearer to the centre of the vortex than at any time during the previous 80 years except once—1822), the corona was perfectly concentric, with no preponderance of light on either side; for the geocentric longitude of the centre was the geocentric longitude of the sun.

In 1878, July 29th, we have the helio-centric longitude of the earth 306°, and that of the centre of gravity about 50°, the difference being 104°. This placed the centre to the right (or west) of the sun, for which see the carefully observed facts seen and recorded at Denver by Prof. Stockwell, whose letter is given on page 53. He is very precise; giving an extension of the corona of three diameters of the sun to the west, and two to the east. Which again confirms the theory.

But why should the corona be more compact or less elongated along the ecliptic plane at a time of maximum sun spots than at the minimum? This question pertains to the solar spot theory; but we will so far anticipate the discussion as to announce the general postulate, that the maxima and minima of solar spots correspond to the polar co-ordinates of the sun (taking its radius for unity) as computed in Table IV. The nearer the centre of the sun coincides with the centre of the system, by the equal distribution of the great planets around that centre, the more gentle are all the activities and energies emanating from the sun; and, consequently, the fewer are the spots. A time of minimum is a time of rest throughout the system. A time of maximum is a time of general disturbance

and of unrest. When the sun is not displaced from his natural position, the corona assumes its normal shape and structure. The polar current which, when deflected by the body of the sun, streams out radially from the axis with its greatest equatorial extension, constitutes the solar radial stream, on whose action so much depends. Of course there are two polar currents which meet at the sun, and are thence deflected along the equatorial (probably the ecliptic) plane. Hence, when the sun is in the centre, the action is regular and uniform, and the innumerable vagrant particles of planetary dust, which are ever circulating around the sun, tossed and whirled about at the mercy of this perpetual blast blowing with lightning velocity from the sun, are more symmetrically disposed than when this polar current encounters the broad disk of the sun in its outward rush as an obstruction to its progress, and can then only involve the sun in a chaotic cloud of particles borne along in eddies, often of double curvature, and in occasional groups and abnormal shafts and rifts, so that the general form of the corona becomes sensibly circular; but the striated wisps and rays which mark the course of the current are too tangled to give either the extension or the carded regularity of the corona of the minima. Yet, for all this, the symmetry of outline is preserved enough to show the relation of the corona to the axis and equator of the sun. Much of the synclinal structure is, no doubt, due to the juxtaposition or duplication of independent masses of curved rays produced by cross currents; but that there are such currents is a fact not only required by the theory, but which has been frequently observed. The author and others detected them in 1869.

Now it is in the lower parts of the corona that these chaotic movements are chiefly observed. We have shown how, by the varying tension of the ether within the sun, that the hydrogen atmosphere is maintained by the velocity of its escape at a mere nominal pressure, when if that

lightening or levitating cause were removed it would settle down as an atmosphere of gas, denser than artificial means have ever formed. We need no eruptions of metallic globules to form the corona. A little cloud of planetary dust, "perhaps the actual materials of the tails of millions of comets, of which they have been stripped in their successive perihelion passages" (as Sir John Herschel suggested about the zodiacal light) scattered with a very sparing hand around the sun, would suffice for the outer corona. We know how light a film of cirrus will obliterate the stars. It cannot require very close packing to make the gossamer threads of the outer corona, when the thickness is reckoned by millions of miles. Now the zodiacal light can be only a doubly sublimed counterpart of the outer corona, as the outer corona is of the lower corona; all three constantly replenished by the accumulated tribute from the outer space, brought down to the sun by the polar current, and prevented from being as readily expelled by the gravitating central force under which they have thus been brought. Thus matter may be accumulated around the sun and sifted by the radial stream, leaving the denser atoms as a permanent meteoric cloud, while the chaff may be carried to much greater distances to be set adrift in the great ocean beyond.

The tail of the great comet of 1680 was emitted in two days. At the end of that time it measured 60,000,000 miles in length. That was at the rate of 350 miles per second, and measured the *lowest* limit of the velocity of the radial stream to which it owed its origin. With such a velocity in an electrical discharge (and perhaps it was many times greater than this, in consequence of the cometary matter being held in check by gravitation and only partaking of *a part* of the motion which impelled it outward), with such a velocity the radial stream would be rendered visible in passing through the most shadowy collection of scattered particles, as may readily be exemplified in an exhausted air-pump. And it is easy to

conceive that every feature of the solar corona may be explained by the rotation of the sun, and consequent ebb and flow of the ethereal tide, outward and inward, as the parts successively recede from, or approach to, the axis. This, combined with the perpetual circulation of the ethereal medium within the solar vortex by the centrifugal force and inertia of the circular current, gives us an intelligible explanation of the changing and peculiar character of the solar corona.

These, then, are our conclusions. The corona is an appendage of the sun, and the symmetry of the corona with the sun naturally follows; pole answering to pole, and equator to equator. The corona must, of necessity, change its form, not only from year to year, but from day to day, and from minute to minute; for the agent of change being in rapid motion, its immense velocity can only belong to electricity. Motions of a thousand miles in a second, in the outside corona or the zodiacal light, probably fall far short of the truth, while the velocity of elevation of the protuberances, the carrying up of the most attenuated haze rendered visible by its immense extension, has no need of solar volcanoes to vomit forth volumes of dense metallic gases to form a chromosphere. The ever restless ether is the *vis viva* of the universe, and its operations in and around the sun are carried on silently, irresistibly, and incessantly. We have seen, also, why the corona may be concentric or non-concentric. Why it may be quadrilateral, hexagonal, circular, or elliptical; and why, with all its formidable array, a comet may sweep through even its densest portions without retardation, any more than a meteor would be retarded by the aurora. As for the polariscope, and the spectroscope, the path is cleared by our theory for placing their revelations on a firmer footing than ever, and the way pointed out to them for making still greater discoveries. We see also an explanation of portions of the corona resembling horse-tails, tangled skeins of yarn, convergent and divergent pencils, synclinal groups, bun-

dles of straight rays a million miles in length, and all the fantastic vagaries of a fluid in rapid motion, whose currents are rendered visible by the foreign particles which it gathers in its course. We see this exemplified in the lines and curves of mist or clouds in our own atmosphere, as well as in the straws and dust of a road-side summer whirlwind.

But it may be said that we have not *explained* the quadrilateral, or cross-like, figure of the corona, and the generally observed fact that the arms of the cross are about 45° from the axis. If this angle is *greater* than 45°, the projections must be nearer the solar equator than 45°, which is, no doubt, generally true; and equally true that in proportion as the sun is displaced from the *centre*, according to our table, the figure of the corona will approach a circle or rounded rectangular figure of irregular internal structure. In 1806 (June 16), the corona is represented within a circular outline, with symmetrical rays diverging in all directions. The plate of this is given in "The Transactions of the American Philosophical Society," 1st Series, Vol. VI., p. 267. According to our Table III., the radius vector of the sun was 1,380,000 miles. In 1851 (July 28), the eclipse is described as if an unequal-sided hexagon were inscribed in an ellipse, as in the sun spot maximum corona of 1871, but more elliptical. In 1851 our table shows $R' = 632{,}000$ miles, which assigns it an intermediate character between the maximum and minimum structures. In 1858, the general outline of the corona is described as circular, with four groups of synclinal curved rays, or cones, whose axes were inclined 45° to the sun's axis. This corona approached near the maximum type—R' being a little over 1,000,000 miles. We next come to the corona of 1860 (July 18), which was decidedly of the maximum type. This was observed by M. Otto Struve, who calls attention to the fact that it differed from the corona of 1851. That one had a well-defined outline. This, on the contrary, resembled a chaotic mass

of clouds, giving the impression of extraordinary agitation. Others describe a white ring with rays starting from the ring perpendicularly, but irregularly distributed around the circumference. The value of R' was 1,240,000 miles. In 1868 we have another eclipse of the intermediate type, and, therefore, the corona is much more irregular in outline, with greater disproportion between the polar and equatorial diameters, approaching the type of the previous eclipse in 1867. But in 1869 there was a greater approach to the maximum type, as can be seen in the figure drawn by the author at Des Moines. The drawings of that corona, in the Eclipse Volume of the R. A. S., from which these various notes have been taken, represent it as quadrangular, with its angles 45° from the sun's axis. Also, as circular, or nearly circular (as by Mr. Naftel's

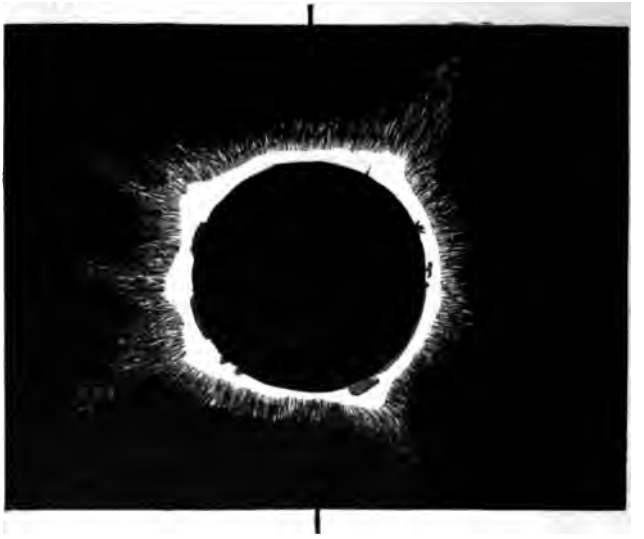


FIG. 7.—CORONA SEEN AT SPRINGFIELD, ILL., AUG. 7TH, 1869, MEEK AND SCHOTTS.

account), without equatorial extensions; R' being = 740,000 miles. Still, it was not of the full maximum type. In 1871 (Dec. 12), the corona was unmistakably of the maximum type, without any difference between the polar

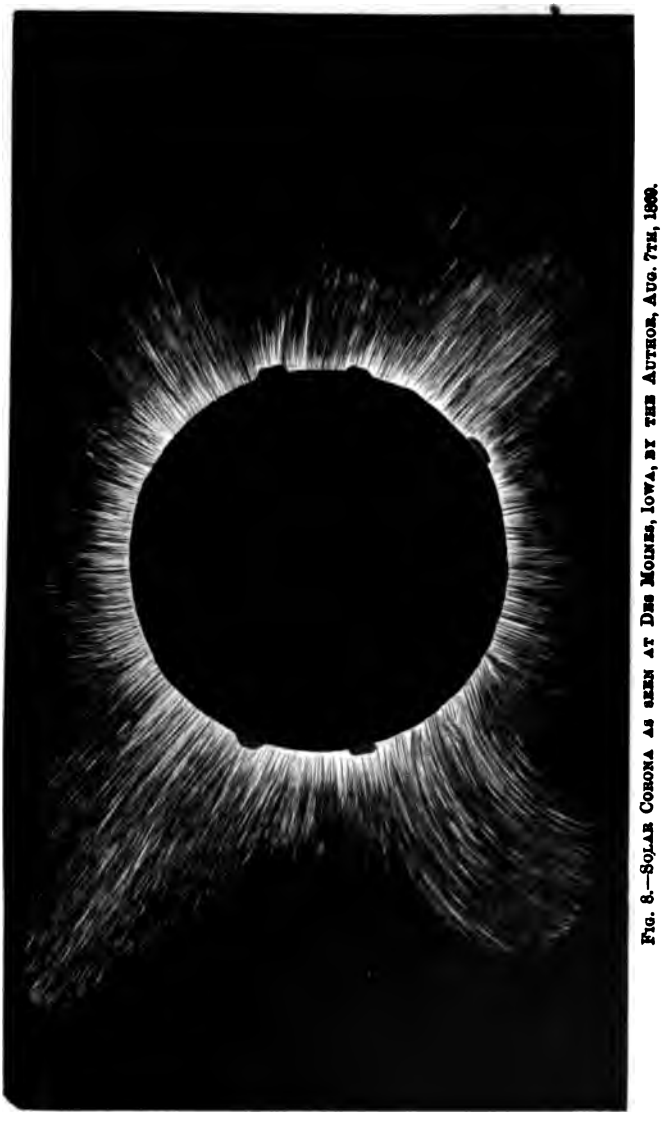


FIG. 8.—SOLAR CORONA AS SEEN AT DES MOINES, IOWA, BY THE AUTHOR, AUG. 7TH, 1869.

and equatorial diameters, but showing cross and convergent rays, with an outline roughly circular. In this

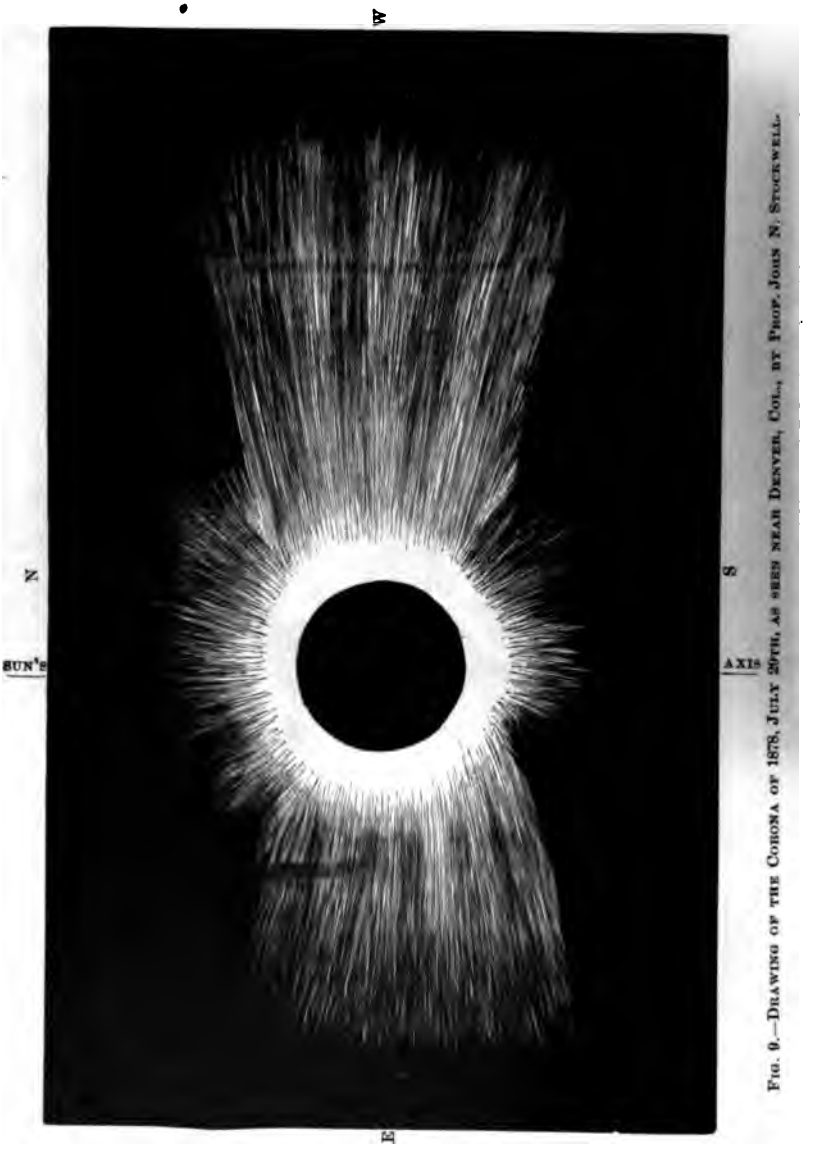


FIG. 9.—DRAWING OF THE CORONA OF 1878, JULY 29TH, AS SEEN NEAR DENVER, COL., BY PROF. JOHN N. STOCKWELL.

case R' was = 900,000 miles. (See Figs. 7, 8, 9, 10, 11, 12 for the eclipses mentioned.)

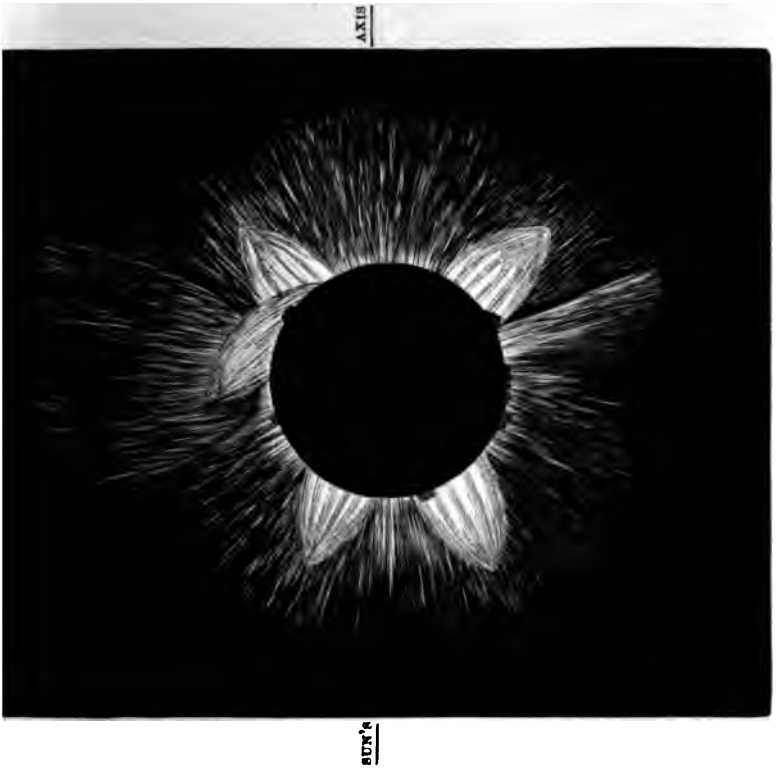


FIG. 10.—DRAWING OF THE CORONA OF 1858, SEPT. 7TH, AS SEEN AT PARANAGUA, BRAZIL.

Now, when the principles of a theory are confirmed by so many apposite facts in accordance with its numerical elements, and not a single case of discrepant result appears, it is but fair to presume that such a theory is, not only more than mere speculation, but is invested with the credentials of truth, and ought to be accepted until proved to be insufficient; for if proved so, the attention thus directed to the special facts on which it rests may be the means of so amending it as to free it from *all* objections.

FIG. 11.—TUPMAN'S DRAWING OF THE CORONA OF 1871, DEC. 12TH, AT JAFFNA, INDIA.

But why should the longest rays be in about 45° of solar latitude? This also is explicable by the theory,

FIG. 12.—GROSCH'S DRAWING OF THE CORONA OF 1867, AUG. 22, SANTIAGO, CHILI.

and fully confirms it, as the reader will see by the accompanying wood-cuts of the coronas of 1871 and 1858, which

were copied from the Eclipse Volume so frequently referred to. The first is by Capt. Tupman, who observed it in Ceylon, and the last by M. Liais, who observed in Brazil. Now, although Capt. Tupman does not show those synclinal groups and conical bundles in his delineation as M. Liais does, yet other observers give great prominence to this feature. Mr. Ranyard (the editor of the volume referred to), on comparing the corona of 1871 with that of 1878, says, "The tree-like forms as well as the synclinal groups which were a marked feature of the corona of December 12, 1871, appear to be absent in the corona of 1878." He also remarks of the corona of 1858, as follows: "Four conical groups of rays were seen by all the observers. A fifth very oblique ray was also observed crossing the N. E. conical group. The background on which these rays were seen was composed of interlacing structure." The corona of 1860 was at the maximum spot period, of which he says: "There was a very distinctly marked group of synclinal structure in the south-western section of the corona, and the axis of the group made an angle of about 45° with the sun's axis." From the observations of M. Lespiault in Spain, the corona seems to have been characterized by narrow groups of conical bundles whose bases rested upon the moon, and by the general interlacing lines (*entrecroisées*) through the whole corona.

In discussing the source of the solar light and heat we shall have to refer to the accompanying diagram (Fig. 21), which explains the origin of these synclinal structures, and the reason why their axes make an angle of 45° with the axis of the sun. The curved lines merely represent the track pursued by the ethereal polar current all around the sun when it is centrally placed. When it is eccentric the symmetry is marred in proportion to the displacement, but not obliterated, because this polar current extends to great distances from the geometrical line of the axis. These curved lines are hyperbolic, with the

sun in the focus, so that a particle of matter descending to the sun, would be ejected from the system were it not for its simultaneous motion in its primitive spiral, which tends in part to neutralize the motion in a conic section; but this is not the place to discuss such a problem.

Let the reader compare the strongly marked synclinal structures of the corona of 1858 with the petals of our coronal rose (Fig. 21), and remember, our theory is, that it is the rush of the ethereal stream through disseminated particles of planetary matter which makes the light, and he can scarcely escape the conviction that these curves mark out the outlines of the synclinal structures in such a collection of atoms, whose numbers diminish rapidly with the distance from the sun. He will also understand how the sun can be so placed in relation to the axis of the vortex as to account for deviations in the angle from 45°, which are sometimes observed, as well as for the want of exact symmetry between opposite sides, east and west and north and south. In fact, it ought to be received as satisfactory proof of the theory—for there is no other theory which can explain these synclinal groups forming a four-rayed star, or those stupendous lines of straight and interlacing streams for which this theory will account—and to impress this the more fully we have placed these figures (10 and 21) side by side.

The descending polar currents of ether may perhaps embrace all latitudes above 45° in both hemispheres of the sun, and, as the sun is supposed to be permeable to these currents, there must be an escape for the ether between latitudes 45° north and 45° south, and a more rapid escape in latitudes midway between 45° and the equator than at the equator. Considering that the ether is compressible and elastic and that it can give motion to, and receive motion from, ponderable matter, it is in accordance with analogy to conclude that the ether feels the resistance of that matter, is compressed or condensed and escapes again, more rapidly and in a more condensed state in lati-

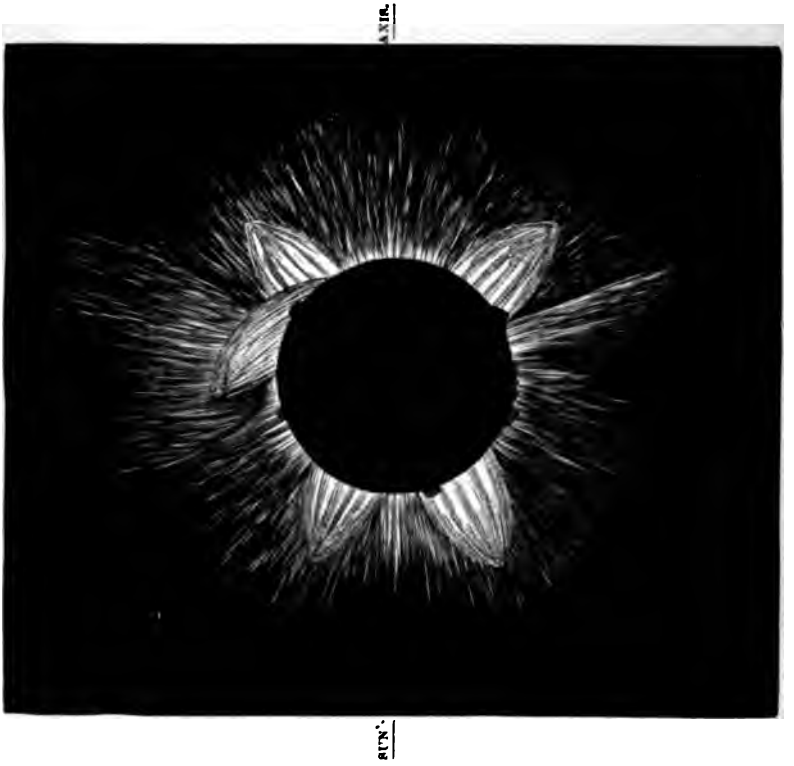


FIG. 10.—DRAWING OF THE CORONA OF 1858, SEPT 7TH, AS SEEN AT PARANAGUA, BRAZIL.

tudes intermediate between 45° and the equator. That it does feel resistance is proved every day by the resistance in our telegraph wires, by the indications of the rheostat, by the flash of the lightning, and in its mechanical effect. But this resistance implies loss of velocity, and it would then, at first sight, appear that the inward current exceeded the outward current in quantity; but it is not so. Taking the superficial area of a sphere equal to unity, the area between 45° of latitude and the nearest

SUN

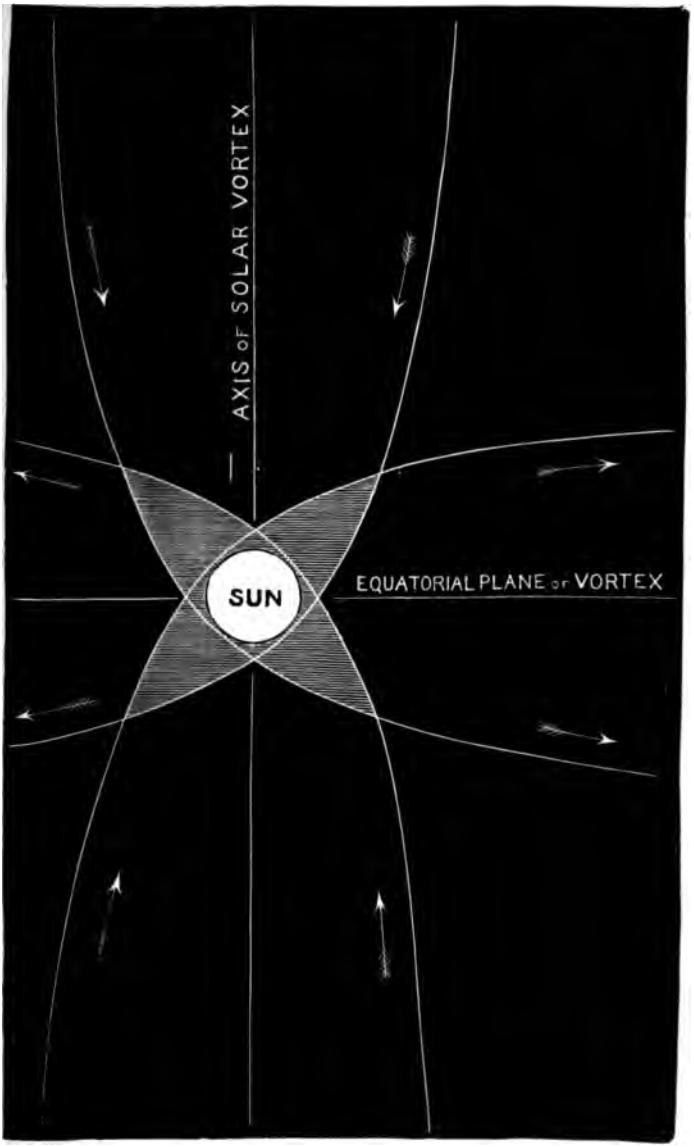
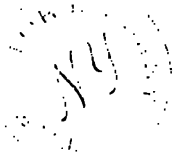


FIG. 21.—SHOWING THE POLAR AND EQUATORIAL CURRENTS OF THE ETHEREAL MEDIUM AROUND THE SUN.



pole is less than one-half of the area between 45° and the equator, or as .293 to .707 ; so if the velocity is retarded, the avenue of egress is proportionally enlarged. Now shall we call this a *remarkable circumstance*, that all the peculiarities of the corona fit so minutely the requirements of the theory and attribute all to chance, or admit that such coincidences unmistakably indicate that we are on the right track. We thus get a clearer conception of this beautiful and rare phenomenon, and become more competent to interpret it aright the more we treat the ethereal medium as we would any other fluid, allowing for its imponderability.

A globe whose surface is uniformly perforated with fine holes, and whose interior is filled with spherical globules completely immersed in still water, and having a strong axis coming above the surface of the water with mechanical appliances for producing rapid rotation, will exemplify this principle by emitting a stronger centrifugal current from latitude 20° than from the equator : but it will require a nice adjustment of the size of the perforations to the size of the globe and of the size of the globules to the velocity of rotation, to succeed. This experiment was made by the author for a very different purpose in 1848, the *annus mirabilis* of California, when devices for washing golden sands engaged many minds.

In the above application of our theory of the corona we have left out many particulars from which we could derive additional support, but we will only allude to one more. While thus the emission from the sun is traced in its progress and explained as a necessary consequence of the rotation of the vortex, it is shown how the gaseous atmosphere of the sun is *levitated* by the escape of the ether (the positive electricity of the sun) just as our own atmosphere is lightened and our barometer depressed by a similar escape when local disturbances of the equilibrium are produced by the passages of the terra-lunar vortices; but this is not quite sufficient to explain

all. It is only a portion of the polar current which strikes the sun, another outside portion strikes the solar corona, bending its outside rays into curves and by intermingling with that portion which emanates *from* the sun, in the way pointed out, causes those partial synclinal groupings and those chaotic and tangled structures which are so frequently seen by observers of eclipses.

From the meagre details yet published of the eclipse of May 6th, 1883, we can only gather that the corona was bright, with five long streamers which indicated equal distribution and no equatorial extensions of the rays; but it is premature to say that the type was of the usual maximum type, which it ought to have been according to our theory, the radius vector of the sun being 1,300,000 miles in May, 1883, and the spot frequency at its maximum.

CHAPTER VI.

THE SOLAR SPOTS AND SPOT THEORIES.

We shall not encumber these pages with all the minute details which this phenomenon presents, for every spot has its peculiar features, and no two groups are strictly accordant in their testimony. Our business is to establish a *theory* which, by explaining the most remarkable facts, gives the only reliable testimony which a theory can give that it is true. The learned may treat our theory of electric vortices as *nonsense;* yet in the very same breath they betray an evident bias in favor of far more nonsensical theories, which have not the stamp of true originality to recommend them. It would be labor thrown away to argue that the spots are solar appendages. That point has been given up long ago; therefore, they are either in, above, or below, the photosphere. They are of immense extent, varying from a visible speck of 300 miles to vast patches of 100,000 miles in diameter, and in 1858 one was observed of 143,500 miles diameter. The formation of these spots is often very sudden, and they disappear as suddenly; but the large isolated circular spot, such as is shown on page 110 (Fig. 16), is of more gradual formation, and sometimes remains comparatively unchanged during an entire period of four weeks. The dimensions just mentioned, of course, include that outer fringe of cloud-like color which incloses the darker core or umbra. The first is called the penumbra, or the imperfect shadow, and is streaked alternately with lighter and darker striæ, but much more uniformly dark at its outer edge where it abruptly terminates in the photosphere. The feathery shafts which shoot into the umbra,

or real shadow, are often much brighter at the margin of the umbra and project into it like the untrimmed eaves of a straw-thatched cottage, making a very irregular outline. This description, however, only applies to spots of the normal type; for in a group, umbræ and penumbræ are strangely mingled. In April, 1882, and the same month in 1883, the author saw large groups which presented an outline similar to a number of little islets in the channel of a shallow rivulet, where the bare sand represented the penumbræ, the wooded centres (sometimes without any margin of sand) the umbræ, and the running stream meandering through a group of such little islets the bright lanes of photosphere. The impression being strongly suggestive of the truth of the analogy.

Another characteristic of the larger umbræ is that tendency to divide into two or more members, and the division is marked, not by penumbral matter alone, but, more frequently, by intensely white and narrow bridges which often are not continuous across the penumbra. This is more frequently observed near the close of a large spot's career, which usually ends by a gradual thinning of the penumbra, and its encroachment on the umbra, until, finally, that also suddenly disappears. The rifts or streaks in the penumbra of a spot converging towards the line joining the two foci (if the spot approaches an ellipse) are not straight, nor are they symmetrically curved except in groups. They rather resemble the little waves in a flat sandy surface, roughly disposed at right angles to the wind. There are also shafts of rays projecting inward on the umbra, and corresponding bundles projecting outward into the photosphere. Besides the evident rapid changes visible under the eye in a spot, and more especially in its secondary surroundings, a unique appearance presented itself September 1st, 1859, to Mr. Carrington, and at the same time to Mr. Hodgson many miles away. Mr. Carrington saw two bright objects of exceeding brilliancy burst forth from the outer edge of the penumbra

of a great spot, and traverse the spot some 36,000 miles in five minutes, in parallel lines, and then disappear—these bright spots being of crescent form 8,000 miles long by 2,000 wide, and distant from each other 12,000 miles. According to Mr. Hodgson, the brightness exceeded that of the photosphere, and "illuminated the *upper* edges of the adjacent spots and streaks, not unlike the edging of the clouds at sunset;" but their dazzling brilliancy merged both into one in his telescope, although his eye was protected. Other appearances of the same kind, though less marked, have been seen by others, and Dr. Peters records the passage of flashes from projecting spurs of the photosphere to opposite spurs, which, finally, unite to form a bridge across the umbra; and, in one case, he saw flashes which traversed a given space with a velocity not less than 120,000 miles in a single second.*

But if the umbra was 50,000 miles in diameter (and the umbra is rarely more than one-third of the whole diameter), it would give half a second for the time of the observation, which the eye can readily appreciate; therefore, there is no good reason for doubting an observation which would prove that nothing but light or electricity can be the agent in producing such rapid motions.

But the characteristic which has been studied with the most assiduity, is that feature which led Dr. Wilson, of Glasgow, to infer that spots were depressions below the general level. This feature may be stated thus: Assuming such to be the fact, the umbra of a spot will represent the bottom of a cup-shaped cavity and the penumbra the sloping side. When a spot appears on the eastern limb the penumbra on the following side of the umbra will present a less oblique angle to the eye than the penumbra on the preceding side, and therefore, if both are of the same breadth, it will *appear* wider. As the spot nears the centre of the disc the two sides will become equal, and

* Light travels 186,300 miles in a second, according to the well-conducted experiments of Master A. A. Michelson, U.S.N. Lightning intensified ten thousand times will explain the above facts.

when the spot reaches the western limb the first relation is reversed, and the preceding side becomes the widest.

The conclusion of Dr. Wilson was based on a spot observed in November, 1769, and this was subsequently expanded by Sir William Herschel, who interpreted it as a general and indisputable fact, showing that the opening of the photosphere caused by upward currents of escaping gas revealed a second canopy (a perfectly reflective canopy by inference) at a lower level, which constitutes the penumbra of a spot, in which a lesser opening reveals the dark (by contrast) and solid body of the sun which constitutes the umbra.

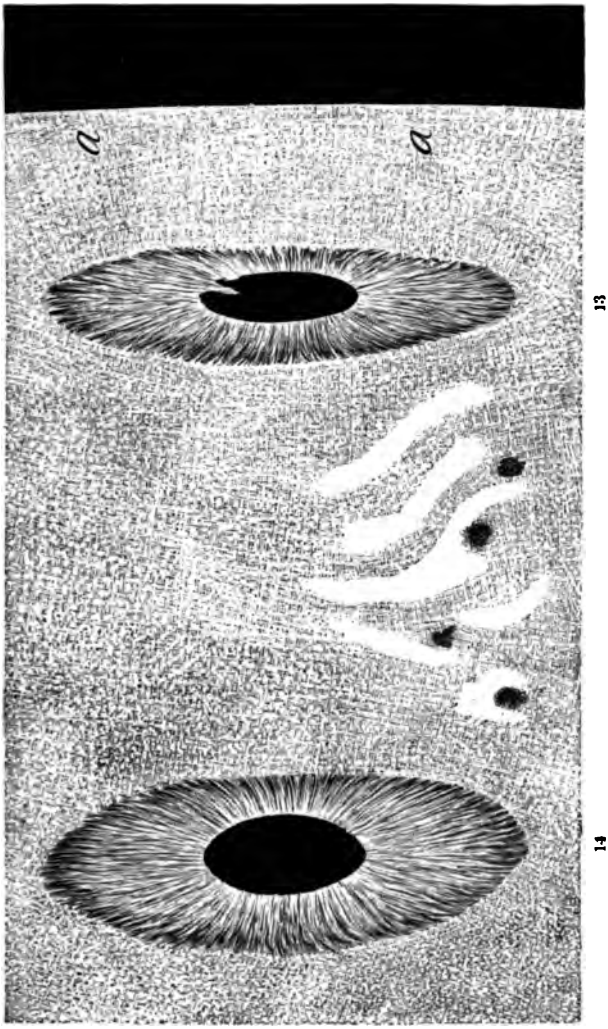
Anyone who is familiar with the solar surface need not be told that this feature of Dr. Wilson's theory is far from being general. The cases are so numerous where the very reverse of this has been observed as to justify a more special examination of the question. We select from our record a case in point, as it was a perfectly isolated spot of compact and regular form. It was first seen by the author through an excellent equatorial on the bluffs of the St. Johns river, near Jacksonville, Florida, in Longitude 81° 37′ 0″ west of Greenwich, and Latitude 30° 18′ 10″ north, and was drawn on March 28th and 29th, and on April 3d, 6th and 8th, 1883, as appears below. (Figs. 14 to 18.)

"Sun observed Wednesday, March 28th, 1883, 11h. 30m. A.M. A large well-defined and regular spot 22″ from eastern limb measured as follows:

Long diameter of penumbra			.....	73″
Short	"	"	"	14.6
Long	"	" umbra	.....	20.2
Short	"	"	"	8.

A ridge of faculæ visible on following side.

"Sun observed Thursday, March 29th, 1883, 11h. A.M. The large spot advanced, showing many minute attendants on following side imbedded in bright faculæ. The distance from limb 102″.2.



FIGS. 13 AND 14 REPRESENT THE SAME SPOT MARCH 29TH AND MARCH 29TH, 1863, NOT INVERTED IN DECLINATION, SHOWING THE GREATER WIDTH OF THE PRECEDING SIDE OF THE PENUMBRA—*a. a.* BEING THE SUN'S EASTERN LIMB, AND THE SPOTS AT THEIR RESPECTIVE DISTANCES FROM THE LIMB, THE SMALL SPOTS AND FACULÆ ONLY VISIBLE ON THE LATTER DATE.

Length of penumbra	73″
Width " "	29
Length " umbra	17.5
Width " "	11

"The ridge of faculæ on the following side very promi-

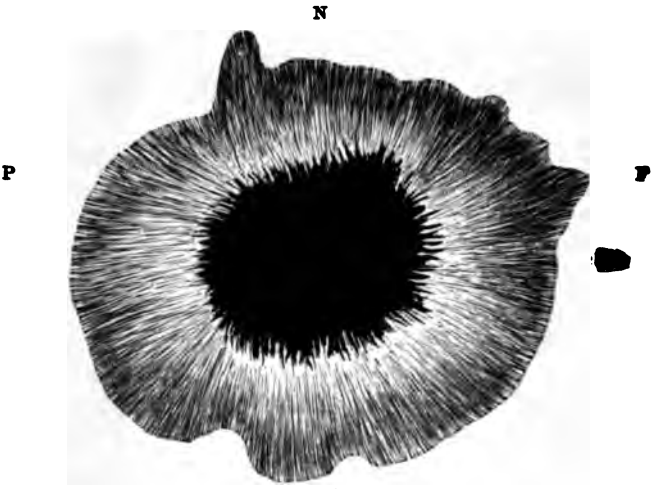


FIG. 15.—SAME SPOT OBSERVED APRIL 3D, NEAR CENTRAL MERIDIAN.

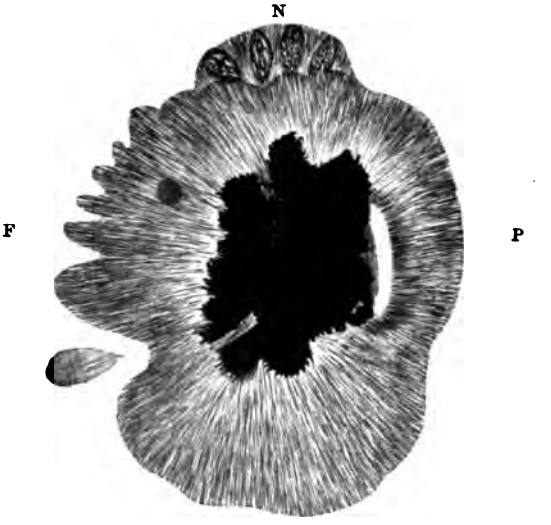
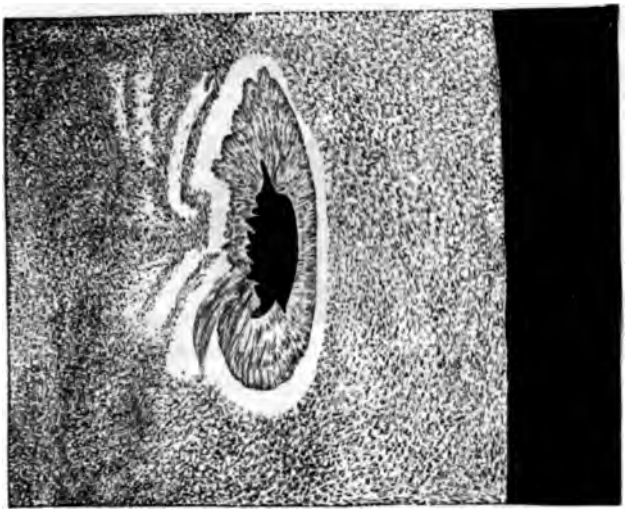


FIG. 16.—SAME SPOT OBSERVED APRIL 6TH, 1883.

NOTE.—Fig. 17 represented the same spot as seen April 7th; but the sky was hazy, and the drawing has been rejected.

SOUTH.



NORTH.

FIG. 18.—SPOT APPROACHING THE SUN'S WESTERN LIMB APRIL 8TH, 1863, HALF INVERTED.

nent with dark patches at north end. There is less difference between penumbra of preceding and following side, but the preceding side *widest*."

The weather now set in cloudy and rainy until Tuesday, April 3d, at 11h. 30m. A.M. "The large spot, which entered March 28th, has passed the central meridian. The small attendants following have all disappeared, leaving the spot of that regular shape common to all large isolated spots. The measures now are:

Long diameter of penumbra ..	93″.8	E.	and	W.
Short " " " ..	89 .4	N.	"	S.
Long " " umbra.....	22	E.	"	W.
Short " " "	17	N.	"	S.

"The long diameter is now east and west, and the whole spot has increased since March 29th. But the penumbra and umbra have not increased equally. The

Length of penumbra	has	increased	from	73″	to	93″.8
Width	"	"	"	"	"	29	" 89 .4
Length	"	umbra	"	"	"	17.5	" 22
Width	"	"	"	"	"	11	" 17."

Now taking the increase of the penumbra and umbra, as above, we find the width of the umbra to be as 11 to 17, instead of 11 to 37, as it should be if the umbra had increased as fast as the penumbra; for 29″ : 89″.4 :: 11″ : 37″, and it has been a very symmetrical spot throughout. Of course, it is possible that the spot was waning, but it may also arise from the rotation exhibiting the two phenomena under a difference of perspective.

If the whole spot be a depression, and the umbra at a lower level than the penumbra, the two will increase in a different ratio with the increase of the visual angle, than would be the case if the two were merely superficial markings, circular and concentric, when the rotation would change both ellipses into circles *pari pasu* as they approached the central meridian of the disc. But suppose, on the other hand, the umbra of a spot be a *protuberance*, and the penumbra on a level—neither an elevation nor a depression. In this case the protuberant umbra hides a portion of the side of the penumbra nearest the limb, and presents a wider and more circular outline on the same side than in the first supposition. Now this is exactly the most prominent feature of the umbra when near the limb of the sun—the outline of the umbra is (in a regularly-shaped spot) almost always more convex to the limb than on the other side, and also more convex *ceteris paribus* than the penumbra.

The accompanying wood-cuts reveal another marked feature in the appearance of this spot, contrary to Dr. Wilson's theory—the inner side of the penumbra was, when near the limb, both at ingress and egress, decidedly the widest.

The same spot was observed April 4th, at 11h. 30m. A. M.

General average of diameters of umbra and penumbra, 4 to 10. Spot decreasing, umbra more oval, weather clear, and observation good. April 5th, weather bad, and spot not observed.

"Sun observed Friday, April 6th, 1883. Same spot observed in clear sky, very little change as to general character, except from perspective. Spots, faculæ and mottlings, show splendidly. The penumbra is a good deal like frost-work on a window pane, inclining to a radial arrangement. There is a very straight ridge of faculæ on south side of umbra, bright as any portion of the sun's disc—four times the width in length. The penumbra is widest on following side—the disproportion increasing as it nears the limb. When the spot was near the eastern limb, March 28 and 29, the excess was on the preceding side, also contrary to Wilson's theory. There is a dark patch visible in the penumbra on the following side (composed of several minute specks), and a long, narrow streak of the faintest gossamer tissue visible on the umbra from south to north, indicating an incipient effort to form a bridge." See this represented in the accompanying wood-cut. (Fig. 16.)

April 7th.—Saturday was cloudy and hazy, but at 2 P.M. the spot was well seen. "It is especially observable that the side of the penumbra nearest the limb is not $\frac{2}{3}$ of the width of the following side. The gauzy streak and black patch in the penumbra have disappeared, leaving the spot regular and compact as at the beginning.

"April 8th.—Sunday, 10 A.M. Same spot observed. Length of penumbra, 46″; width of penumbra, 15″; nearest distance from limb, 31″. The spot is rapidly diminishing. The preceding side of the penumbra is not more than $\frac{1}{4}$ the width of the following side, if the curve was completed on that side; but there is an encroachment of a body of outside faculæ on that side of the penumbra, cutting off about 60° of the ellipse, as represented by the Figure 18. The umbra is getting more rapidly convex on the

preceding side, and nearer the margin of the penumbra, and it stands out fully twice as wide east and west as the preceding side of the penumbra, and, evidently, is much more than half of the whole spot east and west.

"April 9th.—Monday, set in early with wind south east, cloudy and drizzly, which continued until 3 P.M. when the sun shone out, but the spot had disappeared behind the limb."

The theory of Wilson has been so long regarded as the true doctrine of the position of the solar spots, with reference to the photosphere, that it may be regarded as presumption for any one, not admitted within the pale, to question its soundness. Nevertheless, we must do so *unequivocally*. Our own observations force us to regard the solar spots as *elevations*, and not depressions. No doubt Dr. Wilson observed a spot which justified his interpretation. No doubt Messrs. De La Rue, Stewart and others examined and measured 600 spots, and found 75 per cent. of them with penumbræ widest nearest the limb, which would, *pro tanto*, favor Dr. Wilson's theory; but there has been one very important factor overlooked. In the case of the spot whose transit we have recorded there were but few faculæ, but large spots are very generally surrounded by faculæ, in fact imbedded in them, and the level of these faculæ is higher even than the protuberant umbra of a spot. Now, in proportion as a spot is near the limb the faculæ on the side of the spot farthest from the limb will operate as a screen diminishing the width of the penumbra, while the faculæ on the opposite side of the spot can interpose no obstacle to affect its width, and, hence, it is not remarkable that 75 per cent. of the penumbræ measured should show the widest on the side nearest the limb.

But there is another fact which proves that the umbra of a spot is an elevation and not a depression. This, however, is more rarely available as it not only requires assiduous watching but is dependent on rare coincidences

of time and visibility. Sometimes when a large spot reaches the limb the umbra shows a notch or break in the limb which is unmistakable. We copy the following case from our records :

"April 20th, 1882.—Two large groups visible. The chief spot of the following group undergoing rapid changes. The following side of the umbra is getting covered with a greenish olive veil, very dense and in marked contrast with the preceding side which shows no color. This color is also seen on the following side of a companion umbra. The preceding group does not show any such color. There are many curls and waving lines in the following group indicative of circular or meandering currents in the divisions of the general penumbra as shown in Fig. 19."

"April 22d, 9 A.M.—Sun observed. There is one spot in the following group (indicated by an arrow) whose umbra is surrounded by a continuous stream of photosphere, and, outside this, the wide but fragmentary penumbra enclosing the group. Half of the umbra of this spot is overspread with a reddish veil which fits it exactly."

"April 23d.—Sun observed. The large umbra in the *preceding* group is now close to the limb and shows well. It is flanked by a very bright facula as if it were piled up against the side of the umbra, and was brighter on that side as if receiving light from the photosphere. The general penumbra is of large dimensions, and presents a great contrast to what it did yesterday. The following outside margin has darkened, leaving a line of white light beyond towards the limb; and then another dark broken streak, shorter and less dark, at one end of which the umbra is situated with a fine but visible line of light between it and the limb; time 2 P.M. At 2h. 40m. P.M. the spot seems to touch the limb, but wind and clouds cause some boiling. At 3h.20m. P.M. white division between the two lines distinct, especially close to the vanishing umbra.

The streak of white limb half the diameter of the umbra. The photosphere seems brighter near a large group when near the limb than when elsewhere. (This is probably due to faculæ being abundant near a group.) At 4 P.M. the limb shows outside the spot, but it is a mere line just visible with a clear sky and excellent focus. Sun's surface very distinct. At 4h. 45m. P. M. the southern end of umbra in contact with the limb producing a notch, the northern end shows a speck of light between the limb and the umbra. 5h.30m. P.M. the black spot yet plainly visible when you know where to look for it. In this case there is no uncertainty, the long dark line of penumbra being very distinct; also the bright pile within the penumbra in front of the vanishing umbra. There is no longer any cause for doubting the indentation of the limb. There is not the slightest indication of the limb being continuous; all present agreed upon this point. The notch is certainly made, although the breadth of the black spot is much reduced." Huygenian eye-piece of half-inch focus adapted to Herschelian reflecting wedge. Focal length of object-glass exactly seven feet with full aperture of five and a quarter inches.

The cases cited are not the only cases observed, but sufficient for the purpose. No computation can show that a depression can make such a notch; and let it be noted that the umbra was visible for quite a while after the preceding side of the penumbra had vanished. It stood up as a *large* segment of a sphere with straight base, a phenomenon the author has often observed. One case occurred in the previous week on April 18th, 2.30 P.M. We extract from our record: "There is a spot approaching the western limb whose umbra fills the middle space nearly as delineated below. (Fig. 20.)

"It is almost pyramidal in form, and along the base there is a white ridge or bank appearing like the *outer* sunny side of a lunar crater, and so far upholds the theory of the spots being depressions, especially as the farther side

of the penumbra is visible but the near side not visible. This was evidently the ridge of a close facula *hiding* the near side of the penumbra as this side is straight, but the farthest side has an elliptical outline which the vertex of the umbra almost touches. The sharp contrast between the photosphere and penumbra where the white limb comes up to it gives the idea of an inner wall of faculæ, or of a ridge bounding the spot on the inner or penumbral side of the ellipse; and from this appearance it might be said that the penumbra of a spot is a depression below the faculæ, but an elevation above the photosphere which is on the same level as the lowest part of the penumbra.*

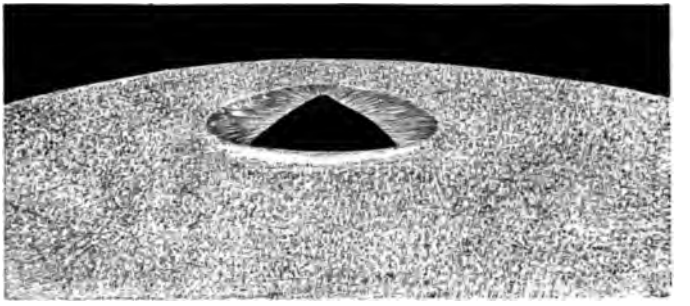


FIG. 20.—A SPOT OBSERVED APRIL 18TH, 1882, NEAR WESTERN LIMB OF SUN.

"April 19th.—Rained hard all day with thunder and lightning; 5 P.M., caught the sun through clouds, but not clearly. Same spot visible near the limb, very black with

* Sir W. Herschel records a similar spot observed Sept. 28th, 1794, of which he speaks thus: "There is a dark spot in the sun on the *following* side (limb). It is certainly depressed below the shining atmosphere, and has shelving sides of shining matter which *rise up higher than the general surface*, and are brightest at the top. The *preceding* shelving side is rendered almost invisible by the overhanging of the *preceding* elevations; while the following is very well exposed. Near the following margin are many bright elevations close to visible depressions."

the narrowest line of light possible, separating it from the limb; but its actual contact could not be observed."

As these two groups must have elicited much interest wherever observed, and as the maximum sun-spot period was approaching, the author devoted much time to their study, hoping to be able to compare notes with others; but he will not farther encumber his pages with the record, only so far as to give his general conclusions confirming opinions which thirty years ago were well advanced to maturity.

1st. There are umbræ and penumbræ of all shades of darkness.

2d. There are umbræ without penumbræ, and penumbræ without umbræ.

3d. Long narrow black lines of umbra and narrow streaks of photosphere often intersect the penumbræ of the same group.

4th. Both the outer and inner margin of the ordinary penumbra has a fringed or raked appearance in the direction of the nearest part of the umbra, without regard to its centre.

5th. The inner side of a penumbra is brighter than the outside, but at the outside margin the photosphere is brighter than it is farther away.

6th. The black umbra is more convex toward the limb, and its width does not diminish as fast as the penumbra as it nears the limb.

7th. Some small spots are formed and others disappear in a few minutes, and observed changes of position are frequently as much as six or seven seconds of arc within the hour, or one mile per second.

8th. There are far more rapid motions occasionally observed, which confirm a frequent, but not an invariable vorticose motion in the central parts of a spot.

Another well marked feature of the solar spots is their limitation to particular zones of the sun's surface. This is so self-evident that it would be superfluous to adduce

the proof. Every observer can satisfy himself of this fact, especially if his telescope be mounted equatorially. We have already alluded to the general fact of spots being most abundant between 10° and 30° of the equator in both hemispheres, and that, at the equator and as high as latitude 40° they are extremely rare. This then constitutes a conspicuous land-mark to steer by, if we would bring our voyage of discovery to a prosperous ending. But the most important feature of all is the periodic character of the intervals between successive maxima or minima of sun-spot frequency. It is the most important for the reason, that the element of time gives it practical importance. Since the discovery of its periodicity by Schwabe, and its more accurate and satisfactory determination by Dr. Wolf, its connection with the period of magnetic change has been established, and if with the magnetism of the earth, why not with its meteorology? Why may not good or bad harvests, rainy or dry seasons, hot summers and cold winters, hurricanes, earthquakes, volcanic eruptions, and desolating plagues be bound up in some (as yet) mysterious way with the solar emanations, when more or less convulsed by internal forces, as evidenced by the number of spots on his surface? There is no room here for jesting. Solar influence for good or ill, or both, must be paramount on the remotest planet of the system, and there can be no nobler physical problem on which man can engage, than is presented by the great source of life and light and energy; and on our humble efforts to add our mite to what is already known, we here, before the world, reverently ask a blessing.

But it is the most important feature in a scientific point of view, for it, alone, gives us a hopeful indication of being the very clue which we are to follow, if we would track the mystery to its lair, and so we shall regard and treat it.

The period itself, however, is subject to great fluctuations; for, although, Dr. Wolf has given 11.11 years as

the average interval between one maximum and the next, yet in his table (Table I. at the end of this volume) he records a maximum in 1788 and the next in 1804, giving an interval of 16 years. Also one in 1830, followed by another in 1837, giving an interval of less than half the former interval; so that while the average may be near the truth, there is no certainty about the length of any future interval for want of knowledge of the cause. This desideratum we propose to supply.

We will now set down in order a few of the conditions to be satisfied in solving the problem of the solar spots.

1st. The spots proceed from within and are attached to the body of the sun.

2d. Their periods of maxima and minima indicate an exciting cause from without, inasmuch as no periodic internal changes are conceivable, independent of external influences.

3d. The spots are elevations rising above the general level of the photosphere, but probably lower than that of the faculæ.

4th. The central portion of the umbra of a spot is higher than the base of the surrounding penumbra.

5th. The central portion of the umbra is of a greater density and of a lower temperature than the gas of the surrounding photosphere.

6th. The average period of maximum frequency of spots is somewhere between 11 and 12 years.

7th. The actual period of the spots must be that of the exciting cause.

8th. The limitation of the spots to particular zones of solar latitude must be prescribed by the exciting cause.

9th. The greater frequency of spots in certain months of the year must also depend on the same exciting cause.

10th. There is a physical connection between solar spots and magnetic variations evidenced by the nearly synchronous occurrence of their maxima and minima.

11th. The spots in all their features are physical phe-

nomena, and therefore the exciting cause must be mechanical and applicable to all.

12th. The spots begin in high latitudes, reach a maximum in lower latitudes, and disappear as they approach the equator at the epoch of minimum.

To satisfy these conditions a great number of theories have been advanced, a few of which we will briefly examine.

Galileo, who was probably the first telescopic discoverer of sun spots, considered them as clouds floating in the solar atmosphere. Others have considered them as rafts of scoria, while some have even thought them to be portions of the solid body of the sun alternately flooded and left bare by solar tides. We have already examined Herschel's expansion of Dr. Wilson's theory of the spots being the true surface of the sun covered by a canopy of clouds which the photosphere, in turn, covered, except when a rush of gas from below pushed these veils aside, and thus revealed the solid solar surface, which showed dark by contrast with the intense light of the upper stratum.

Sir John Herschel, in view of the fact that the spots are confined to narrow zones of latitude on each side of the equator, seeks in the circulation of atmospheric fluids ("similar to our trade and anti-trade winds from the poles to the equator and back again, combined with the earth's rotation") for the cause of the solar spots, and remarks, in conclusion, that "the spots would come, on this view of the subject, to be assimilated to those regions on the earth's surface, in which, for the moment, hurricanes and tornadoes prevail—the upper stratum being temporarily carried downwards, displacing by its impetus the two strata of luminous matter beneath—the upper, of course, to a greater extent than the lower, and thus, wholly, or partially, denuding the opaque surface of the sun below." This is substantially the same view as held by Sir William Herschel, with the difference that Sir John looks to

a whirlwind above the photosphere to open a gap in the enclosing strata, while Sir William assigned the task to an upward current. But if the greater thickness of the solar atmosphere caused by the centrifugal force of rotation produces the zones of solar tornadoes, in consequence of the inferred greater heat there, how is it that the equatorial zone, 15° or 20° wide, is more exempt from spots than latitudes above 10° and less than 35° north and south? This, it is true, is a feature which *does* assimilate the spots to the hurricanes of the tropics which are never found at the equator, and we may implicitly trust the analogy in tracing the two phenomena to the same principle; but this peculiarity is one of the most marked features of the spots we are called upon to explain. Why are the spots never (never with a very slight reservation) found outside the zones comprised between the latitudes 10° and 35°? Faye's theory is, in its main feature, that solar spots are solar storms. In 1853, the author considered them as "solar storms" (vide "Outlines," page 152), and referred them to solar *electrical vortices;* assigning a physical reason why they were limited in latitude, and increased and waned in development every eleven or twelve years. Faye thinks that our terrestrial whirlwinds and tornadoes are produced in the same way, that is by the relative velocity of drift of contiguous portions of the solar and terrestrial atmospheres.

Another popular theory is that of Secchi's, who attributes the formation of spots to the falling down of masses of ejected vapors after being cooled by their elevation. Professor Young looks upon the spots as depressions in the photosphere into which the overlying gases flow; the cause of the temporary depression being a collapse from the escape of the confined gases, as if the photosphere were analogous to a shell sufficiently compacted as to resist a little pressure. As for the meteoric theories, they cannot be accepted by even a tyro in solar physics, and the theory of Zöllner has as little to commend it.

We pass then to the astronomical theories. These are founded on the positions of the planets Mercury, Venus, and Jupiter, by combining them in pairs, both as respects their allineation, and their approach to, and recess from, the sun. How the planet Mercury should wield such an influence is incomprehensible. His attraction or tidal influence may be set down as nil, and so also of Venus. As for Jupiter, while its period favors the idea that it may be a factor in determining the maximum spot period, it unfortunately happens that the accordance of the maxima and minima of spots, with its varying distance, is only transient, and as frequently contradicts the theory as supports it. Others see in the conjunction of Jupiter and Saturn every ten years a better average interval than the period deduced by Wolf, and only last year (January, 1882), "M. Duponchel read a paper before the Academy of Sciences at Paris, contending that the period followed the period of Jupiter, showing that the *true theory* was beginning to impress itself on men of science. He gives 11.857 years as the period, and that the next maximum will be in 1888 or 1890." (See Observatory, No. 57, 1882.) Now, if Jupiter be the sole cause, it can only be by proximity, as the present theory is excluded, and as the perihelion of the planet advances very slowly, the sidereal period and the anomalistic period may be considered equal; but it is impossible to reconcile Jupiter's period with the solar spot period for any length of time, and therefore this idea must also be given up; for the maxima of sun spots have not occurred simultaneously for many years with the perihelion passage of Jupiter.

CHAPTER VII.

OUR THEORY OF THE SOLAR SPOTS.

THE principles on which we rely are substantially the same which we published in 1854, as an incidental branch of our "Mechanical Theory of Storms" (the "Outlines" previously referred to).

From what we have already advanced concerning the origin and cause of the corona, and the consequences flowing from the admission of an ethereal medium with all the attributes of matter (gravitation excepted), we might pass at once to the elucidation of the twelve secondary problems we have selected as tests of the truth of that theory, which is indisputably our own. But when the novelty of the arguments, and the intrinsic difficulty of the subject are considered, the general reader will not regard it as superfluous if we recapitulate some portion of the details we have already placed before him.

The solar system, and, by parity of reasoning, all other stellar systems, are placed in the axes of so many ethereal or electrical vortices, in which, while the laws of motion are rigidly observed, there may be an endless variety of phenomena. Endless in its full, literal sense, that no two suns, no two planets, no two created entities throughout the universe, are identical in a single feature, except in the state of simple primitive atoms, and the same may be predicated of the stellar vortices. If central mass and velocity of rotation are duly arranged, then the central body may be a nebulous star, like our own sun, invested with a far-reaching halo of lenticular form when seen obliquely, as we see it. Epsilon Orionis is another similar star whose zodiacal light is far more extensive. When

seen at right angles to the line of sight such halos will be circular, but more rarely seen, as the light-reflecting planetary dust, which renders the radial stream of a star visible, is more diffuse.

The varied combinations of relative masses and distances of the secondary bodies of each system, and the time of rotation of their primaries, together with the inclination of the general plane of motion, is a prolific source of variability in the light of the stars. If the masses of some stars are relatively small as compared with the planets dependent on their light, then there will be intervals of maximum displacement from the centre of gravity of their system, which will, perhaps, cause maximum spot periods much longer than ours; but differences in distance and variety in orbit and rotation periods will affect the result, and may account for the variation of a star's light amounting to several magnitudes. It is easy, also, to see how the mean period itself may be slowly variable, or steadily increasing, or decreasing, during a long cycle of years. With such a key, the variable stars present stronger claims than ever on amateur observers, although such a cause for variability does not preclude the possibility of there being stars with a portion of their surfaces dark as compared with other portions, and rotating in a very long or short period. Neither does it preclude the possibility of there being little stars with very large planets revolving around them (or, perhaps, effulgent stars of small mass revolving around very massive planets), and causing a variability by a partial eclipse, as perhaps in the case of Algol or Beta Persei, S. Cancri, Delta Libræ and a few others, but that the principal cause of the variability of many stars with an approximate regularity of period is due to the same cause which produces the solar spots, would be infatuation to deny. Here we have a satisfactory explanation of this mystery without outraging a single principle of science—physical, mechanical, or mathematical; but if, from pride of caste, or from illib-

eral prejudice, we refuse to accept the key here placed in our hands, we shall go down to posterity branded with the odious mark of an intellectual stultification, for which no excuse can be offered.

Taking this obvious corrollary of the fundamental principle we have laid down as the truth, that in a vortex of an imponderable fluid, in which various ponderable bodies circulate, the axis of that vortex must pass through the centre of gravity of the various bodies constituting its ponderable elements, and, therefore, where there is a large preponderating mass in the centre which exceeds the united masses of all the other bodies in a given ratio, the total displacement of the central body from the axis of that vortex will be shown by the sum of the rectangular co-ordinates of those several masses multiplied by their distances—the unit in each case being the mass and semi-diameter of the central body.

In the case of the sun we take the masses and distances of the four great planets, Jupiter, Saturn, Uranus, and Neptune, with their heliocentric longitude and true anomaly, and derive the displacement of the sun's centre in solar radii, and the longitude of that centre, or, rather, the longitude of the centre of gravity, which differs from the other, of course, by 180°. These have all been calculated for over one hundred and twenty years, and the result will be found in our Table II. at the end, calculated from the following data to the nearest minute of longitude, and to the fourth place of decimals in displacement:*

* Table II. contains the rectangular co-ordinates of the centre of gravity of the solar system as derived from each one of the four great planets in their appropriate columns—the two last columns, headed X and Y, being the algebraic sum of all four, for the 1st of January of the year designated in the first column.

EQUINOX OF THE TABLES, 1850.	THE PLANETS' MASSES.	DISTANCE IN UNITS OF EARTH'S DISTANCE.	SUN'S SEMI-DIAMETER	RATIO OF SUN'S SEMI-DIAMETER TO EARTH'S DISTANCE.
Sun	1		433200	$\frac{1}{214.4}$
Jupiter	$\frac{1}{1047.88}$	5.202776		
Saturn.....	$\frac{1}{3501.60}$	9.538786	Parallax	
Uranus.....	$\frac{1}{21000}$	19.182390	8."8	
Neptune	$\frac{1}{19700}$	30.036269		

From that Table II., supplemented by our Table III., we gather the fact that

WHEN THE DISPLACEMENT OF THE SUN IS AT A MAXIMUM THE FREQUENCY OF THE SOLAR SPOTS IS ALSO AT A MAXIMUM, AND WHEN THE DISPLACEMENT IS AT A MINIMUM, THE FREQUENCY OF THE SOLAR SPOTS IS AT A MINIMUM.

As our tables of the co-ordinates of the sun are calculated for the first of January of each year, we have compiled our table of Wolf's sun-spot numbers for that date, by taking the sum of the numbers for each January and for the preceding December, as the true average for January first (see Table II.). We have (in Fig. 24) drawn the two curves, by taking Wolf's numbers as above, and compared them with the computed co-ordinates, and find very little difference in the comparison. Now it will be noted the only real discrepancy which occurs in the comparison is in the numbers pertaining to the close of the last century, where our Table III. shows a maximum of sun spots from 1791 to 1794, and not 1788 as according to Wolf. When we consider how uncertain were the sources, a hundred years ago, of the very data by which Dr. Wolf's relative numbers have been determined, we may question the accuracy of those numbers for that particular epoch.

Even Prof. Young confesses that observations of the sun spots near the close of the eighteenth century "are so meagre and unsatisfactory that the evidence as to the precise time of maxima and minima is very incomplete. It is even doubtful, as has been said before, whether there should not be recognized an additional sun-spot maximum in 1795 over and above those enumerated by Wolf." But he evidently regards the numbers given by Wolf as generally reliable; for when comparing the immense difference in the interval between the maxima of 1830 and 1837 (amounting to only 7 years) with that between 1788 and 1804 (equal to 16 years), he says, "A portion of this great variableness of period may perhaps be due to the incompleteness of our observations; *but only a portion.*" (See Fig. 24 at the end.)

The periodicity of the solar spots has, by some occult influence, crowded itself to the front when we intended to have reserved it to the last, and we are thus prematurely required to vindicate its claims to such precedence. If the reader will turn to our chart where we have drawn side by side the curve given by Dr. Wolf's numbers with the *dotted curve* of the polar co-ordinates of the sun, as given by the *four* great planets from 1783 to 1904, he will see that they do not coincide. On the same chart he will see the same Wolfian curve compared with the polar co-ordinates of the sun into which a hypothetical element (a fifth great planet) has been introduced; and, although he may detect trifling discrepancies in the comparison, yet if he be at all conversant with the science of probabilities and will go through with the calculation, he will find that (supposing that our comparison be limited to the present century and the coincidences exact) fifteen consecutive coincidences without reference to their character, give over one hundred thousand millions to one that these coincidences are not the result of chance; and if the farther condition be added that the maximum computed coincidences shall correspond with the maximum observed

coincidences, and the minimum with the minimum, the chances against such agreement being the result of chance are as three hundred and eighty millions of millions to one. Such odds can well afford a trifling deviation from exact coincidence without vitiating its claims as representing a truth.

Now this question of periodicity has given physicists more trouble than any other question in solar physics; studiously ignoring the fact that in 1853 the author published the only possible solution of the problem in his "Outlines of a Mechanical Theory of Storms." As that work was nothing more than an outline *prepared* especially by him for the Smithsonian Institution, its reference to other kindred phenomena was necessarily of the briefest character; yet, inasmuch as the author contended that solar spots were produced in the same way and by the same causes which are chiefly instrumental in disturbing our weather—the main-springs of our atmospheric circulation from the poles to the equator—he gave, in that work, a short sketch of the application of his theory to the solar spots, which he feels it but just to transcribe in full in view of the somewhat different interpretation of the facts which an additional thirty years' study and observation of those spots has imposed. In that article it will be seen that the author's faith in the principles of the theory never failed him. In 1845 or 1846 the author had given to Prof. O. M. Mitchel, Director of the Cincinnati Observatory, a general idea of his theory, alluding to the new force in astronomy which he had discovered, in an article on comets, part of which was published in the "Sidereal Messenger" for that year. But it was found difficult to reconcile the theory with Schwabe's table of the spots, and hence, before the discovery of Neptune, the author had suspected *the existence of another planet in the system.* When Neptune was discovered there seemed no way of reconciling the two without another additional planet; but this was, for the time, clogged with the incu-

bus of an implied necessity of limiting the maximum effect of displacement of the sun's centre to a distance barely equal to the sun's radius. This necessity, however, was more fancied than real; but, owing to the radical nature of the theory which admitted of no half-way compromises with those then held of the general structure and constitution of the solar system, and the wide field it opened for investigation, it required more time and labor than the author was then able to devote to it. What he has done has been done under the strong conviction that he had discovered a truth; and that if those who were professionally engaged in such pursuits refused to follow his lead, it would devolve upon himself, as a duty he owed to the world, to finish the work he had begun. In the prosecution of this resolve he has necessarily neglected opportunities of doing what others would have done; that is, of attending to more profitable business; but failing health and increasing years have latterly warned him to put his theory in order, so far as he has succeeded in developing it, lest he might be called upon to abandon to the cold charities of the scientific world a question which he may truly say is the fruits of a life-long labor. The article reads as follows: "We have yet many phenomena to investigate by the aid of the theory, and we will develop them in that order which will best exhibit their mutual dependence. The solar spots have long troubled astronomers, and to this day no satisfactory solution of the question has been proposed; but we shall not examine theories. It is sufficient that we can explain them on the same general principles that we have applied to terrestrial phenomena. There can be but little doubt about the existence of a solar atmosphere, and, reasoning from analogy, the constituent elements of the sun must partake of the nature of other planetary matter. That there are bodies in our system possessing the same elements as our earth, is proved by the composition of meteoric masses, which, whether they are independent bodies of the sys-

tem, or fragments of an exploded planet, or projected from lunar volcanoes, is of little consequence; they show that the same elements are distributed to other bodies of the system, although not necessarily in the same proportion. The gaseous matter of the sun's atmosphere may, therefore, be safely considered as vapors condensable by cold, and the formation of vortices over the surface of this atmosphere brings down the ether and causes it to intermingle with this atmosphere. But, from the immensely rapid motion of the polar current of the solar vortex, this ether may be considered to enter the atmosphere of the sun with the temperature of space.

"Sir John Herschel, in commenting on the theory of Mr. Redfield before the British association, convened at Newcastle in 1838 (vide Silliman's Journal, Vol. XXXV., page 283), suggested an analogy to terrestrial hurricanes, from a suspected rotation and progressive motion in these spots. From their rapid formation, change of shape and diameter, this view is allowable, and taken in conjunction with the action of the ethereal currents will account for the phenomena. The nucleus of the spot is dense, like the nucleus of a storm on the earth, and surrounded by a penumbra precisely as our storms are fringed with lighter clouds, permitting the light of the sun to penetrate. And, it has been observed, that these spots seem to follow one another in lines on the same parallel of solar latitude (or nearly the same) exactly as we have determined the action of the vortices on the surface of the earth from observation. These spots are never found in very high latitudes—not much above 30° from the solar equator. If we consider this equator to be but slightly inclined to the plane of the vortex, this latitude would be the general position of the lateral solar vortices, and, in fact, be confined principally to a belt on each side of the solar equator between 15° and 3° of solar latitude, rather than at the equator itself. This, it is needless to say, is actually the case. But, a more capital

feature still has been more recently brought to light by observation, although (the suspicion was) previously familiar to the author, who, in endeavoring to verify the theory, seriously injured his sight by observing with inadequate instrumental means. This is the periodicity of the spots.

"We have already observed that there is reason to suppose that the action of the inner vortex of the earth is probably greater than that of the outer vortex, on account of the conflicting currents by which it is caused. And the full development of this vortex requires that the central vortex or mechanical axis of the system shall be nearly tangential to the surface. In this position, the action of the central vortex is itself at a maximum; and, when the planets of the system are so arranged as to produce this result, we may expect the greatest number of spots. If the axis or central vortex approaches to coincidence with the axis of the sun, the lateral vortices disappear, and the central vortex being then perpendicular to the surface, is rendered ineffective. *Under these circumstances, there will be no spots on the sun's disc.* When, on the other hand, all the planets conspire at the same side to force the sun out from the mechanical centre of the system; the surface is too distant to be acted on by the central vortex, and the lateral vortices are also thrown clear of the sun's surface, on account of the greater velocity of the parts of the vortex, in sweeping past the body of the sun. In this case there will be but few spots. The case in which the axis of the vortex coincides with the axis of the sun, is much more transient than the first position, and hence, although the interval between the maxima will be tolerably uniform, there will be an irregularity between a particular maximum, and the preceding and subsequent minimum.

"The following Table exhibits the solar spots as determined by Schwabe, of Dessau:

YEAR OF OBSERVATION.	GROUPS OF SPOTS OBSERVED.	NUMBER OF DAYS.
1826	118	277
1827	161	273
1828	225	282
1829	199	244
1830	190	217
1831	149	289
1832	84	270
1833	33	267
1834	51	273
1835	173	244
1836	272	200
1837	333	166
1838	282	202
1839	162	205
1840	152	263
1841	102	283
1842	68	307
1843	34	324

"Previous to the publication of this Table, the author had inferred the necessity of admitting the existence of another planet in the solar system, from the phenomenon of which we are speaking. He found a sufficient correspondence between the minima of spots to confirm the explanation given by the theory, and this was still more confirmed by the more exact determination of Schwabe; yet there was a little discrepancy in the synchronous values of the ordinates, when the theory was graphically compared with the Table. Previous to the discovery of Neptune, the theory corresponded much better than afterwards, and as no doubt could be entertained that the anomalous movements of Uranus were caused by an exterior planet, he adopted the notion that there were two planets exterior to Uranus, whose positions at the time were such that their mechanical effects on the system were about equal and contrary. Consequently, when Neptune became known, the existence of another planet seemed a conclusion necessary to adopt. Accordingly, he calculated the heliocentric longitudes and true anomalies, and the values of radius vector, for all the planets during

the present century, but not having any planetary tables, he contented himself with computing for the nearest degree of true anomaly, and the nearest thousand miles of distance. Then by a composition and resolution of all the forces, he deduced the radius vector of the sun, and the longitude of his centre, for each past year of the century. It was in view of a little outstanding discrepancy in the times of the minima, as determined by theory and observation, that he was induced to consider as almost certain the existence of a theoretical planet, whose longitude, in 1828, was about 90°, and whose period is from the theory about double that of Neptune. And for convenience of computation and reference, he has been in the habit of symbolizing it by a volcano. The following Table of the radii vectores of the sun, and the longitude of his centre, for the years designated in Schwabe's Table, is calculated from the following data for each planet:

PLANETS. SYMBOLS.	MASSES. SUN UNITY.	MEAN DISTANCES IN MILES.	ECCENTRICITIES IN PARTS OF THE MAJOR AXIS.	LONG. OF PERIHELION.
☿	$\frac{1}{1048}$	494,800,000	0.0481	11°
♄	$\frac{1}{3510}$	907,162,000	0.0561	89°
♅	$\frac{1}{23000}$	1,824,290,000	0.0166	167°
♆	$\frac{1}{20000}$	2,854,000,000	0.0088	0°
△	$\frac{1}{28000}$	4,464,000,000		

DATES.	RAD. VECTOR.	SUN'S LONG.	ORDINATES.	NO. OF SPOTS IN SCHWABE'S TABLE.
Jan. 1st. 1826.	528,000	320°	+ 84	118
" " 1827	480,000	339	+ 36	161
" " 1828	432,000	352	− 12 Max.	225 Max.
" " 1829	397,000	38	− 47	199
" " 1830	358,000	71	− 86	190
" " 1831	324,000	104	− 120	149
" " 1832	311,000	144	− 133	84
" " 1833	300,000	188	− 144 Min.	33 Min.
" " 1834	307,000	220	− 137	51
" " 1835	338,000	263	− 106	173
" " 1836	389,000	302	− 55	272
" " 1837	419,000	337	+ 25 Max.	333 Max.
" " 1838	488,000	3	+ 44	282
" " 1839	551,000	29	+ 107	162
" " 1840	632,000	51	+ 188	152
" " 1841	680,000	80	+ 236	102
" " 1842	730,000	105	+ 286	68
" " 1843	766,000	128	+ 322	34 Min.
" " 1844	783,000	152	+ 339 Min.	52
" " 1845	772,000	174	+ 328	114
" " 1846	728,000	196	+ 284	157
" " 1847	660,000	218	+ 216	
" " 1848	563,000	240	+ 119	Observed Max.
" " 1849	447,000	261	+ 3 Max.	
" " 1850	309,000	283	− 135	
" " 1851	170,000	323	− 274	
" " 1852	53,000	41	− 391 Min.	
" " 1853	167,000	133	− 277	
" " 1854	315,000	160	− 129	
" " 1855	475,000	183	+ 31 Max.	
" " 1856	611,000	203	+ 167	
" " 1857	720,000	225	+ 276	

"It is necessary to observe here, that the values of the numbers in Schwabe's Table are the numbers for the whole year, and, therefore, the 1st of July would have been a better date for the comparison; but, as the table was calculated before the author was cognizant of the fact, and being somewhat tedious to calculate, he has left it as it was, viz.: for January 1st of each year. Hence the minimum for 1843 appears as pertaining to 1844. The number of spots ought to be inversely as the ordinates approximately—these last being derived from the Radii Vectores minus the semi-diameter of the sum=444,000 miles." (This error vitiated the spot theory at that time.)

"In passing judgment on this relation, it must also be borne in mind, that the recognized masses of the planets cannot be the true masses, if the theory be true. Both sun and planets are under-estimated, yet, as they are, probably, all to a certain degree proportionally undervalued, it will not vitiate the above calculation much.

"The spots being considered as *solar storms*, they ought also to vary in number at different times of the year, according to the longitude of the earth and sun, and from their transient character, and the slow rotation of the sun, they ought, *ceteris paribus*, to be more numerous when the producing vortex is over a visible portion of the sun's surface.

"The difficulty of reconciling the solar spots, and their periodicity to any known principle of physics, ought to produce a more tolerant spirit among the scientific for speculations even which may afford the slightest promise of a solution, although emanating from the humblest inquirer after truth. The hypothesis of an undiscovered planet, exterior to Neptune, is of a nature to startle the cautious timidity of many; but, if the general theory be true, this hypothesis becomes extremely probable. We may not have located it exactly. There may be even two such planets, whose joint effect shall be equivalent to one in the position we have assigned. There may even be a comet of great mass, capable of producing an effect on the position of the sun's centre (although it follows from the theory that comets have very little mass). Yet in view of all these suppositions, there can be but little doubt that the solar spots are caused by the solar vortices, and these last made effective on the sun by the positions of the great planets, and, therefore, we have indicated a new method of determining the existence of all the planets exterior to Neptune. On the supposition that there is only one more in the system, from its deduced distance and mass, it will appear only as a star of the eleventh magnitude, and, consequently, will only be recognizable

by its motion, which, at the greatest, will only be ten or eleven seconds per day."

(See "Outlines," page 147 to 153.)

In the above we have frankly exposed the weak point of our then immature theory of the solar spots, and the consequent error in the assigned longitude of our suspected planet. Then we were forced to give the controlling influence to the vortices produced by the displacement of the sun's centre, and a secondary part to the amount of that displacement.

This great difficulty arose from the influence of preconceived views. We could not reconcile the idea of a planet in our system with a retrograde motion; but when that objection was overcome, the path was cleared of obstructions and its location became easy.

That undiscovered planet (or planets having masses and distances equivalent, in their mechanical effects, in displacing the sun to the *one* of our theory) has caused us an immense amount of work; but its final location near the place assigned it, with mass and motion in nowise repugnant to probability, is endorsed by the verification it gives to a series of numbers representing the resultant polar co-ordinates of the sun, in close harmony with the numbers given by Dr. Wolf as the relative sun-spot numbers for the same years. And this for nearly a whole century.

Yet it must be confessed that, at first sight, the idea of a retrograde planet presents a formidable argument against our general theory. We will candidly state it. If, at a given distance from the sun, a planet is found with retrograde motion, the inference is legitimate that the ethereal medium is also retrograde at that distance; and, therefore, at the distance where the direct motion changes to retrograde, the ethereal medium must be at a stand, and constitute a limit to the ethereal vortex motion, and to the centrifugal force on which the rarefaction of the interior, and the existence of the great expulsive stream

of electricity depends. But the argument is not formidable. If the planet (in order to designate it we will accent in the order of the other planets and call it Planet VIII.) be an index of the motion of the ether, the rarefaction will be independent of the *direction* of the motion, and the centrifugal force will be maintained according to *some* law of the distances, if not following precisely the Keplerian law. Following the guidance of analogy, indeed, we ought to expect such a change. The whirlwind and the whirlpool have their limits, and the cyclone is stated to have its anti-cyclone; so may a vortex have its anti-vortex according to its magnitude; and the future race of astronomers must have many unexpected surprises in store for them, even as we of this age are occasionally excited by the wonderful revelations of nature, which often rudely upset what are called established truths.

DEDUCED ELEMENTS OF PLANET VIII.

Epoch, January 1, 1883.

a = 47. Earth's distance unity.

L = 115° at epoch.

M = $\frac{1}{12000}$ Sun = unity.

Motion *retrograde*. Orbit provisionally taken as circular, and inclination 0°.

Certainly the idea of the existence of a retrograde planet in our system, so contrary to all analogy, is not calculated to gain converts at first sight. But let us reflect. In the case of the satellites of Uranus, we have certainly retrograde motion. The satellite of Neptune is also probably retrograde. In cometary and meteoric astronomy, we have quite as many orbits retrograde as direct, and when we appeal to the analogy of vortex motions in the magnetic and galvanic currents, we encounter anomalies which can only be reconciled by reverse currents, and even in our little summer whirlwinds an outside reverse current can sometimes be detected. But let us resort to figures. While the mass of the hypothetical

planet is only half that of Saturn, its distance is about five times greater, and therefore its power to displace the sun, compared with that of Saturn is, roughly, as 5 to 2. But if we compare it with the united influence of Saturn, Uranus, and Neptune, we find it still superior; for while these three are only competent to displace the sun 500,000 miles, Planet VIII. displaces it over 600,000; so that, as the displacement due to Jupiter alone is over 450,000 miles, it follows that the conjunction of these two planets, IV. and VIII., determines the period of maxima and minima for the solar spots.

Wolf's period, by his own showing, is liable to the uncertainty of $\pm$ 0.307 of a year = 112 days.*

Now the synodical period of two planets depends on their respective angular velocities, and the direction of their motions; but their angular velocities are inversely as their periodic times. When the motion of both planets is direct, the interval between the consecutive conjunctions is increased; but when one is retrograde the interval is diminished. Call their respective velocities V and v, and x the arc by which a complete revolution of Jupiter is diminished; then

$$V : v :: 360^\circ - x : x$$

and

$$V + v : v :: 360^\circ : x$$

so that

$$\frac{x}{v} = \frac{360^\circ}{V + v}$$

In the case before us, Jupiter's sidereal period is 4330.6 days = per day	0°.083129
The period of Planet VIII. = 116,880 days, giving a motion per day of	0°.003079
The sum of which is	0°.086208

* In the report of the Greenwich observations and results for 1877, in the *Astronomical Register* for July, 1880, this period is given as 11.7 years.

Therefore, $\frac{360^\circ}{0^\circ.086208'}$ gives the synodical period equal 4176 days, which is 158 days over 11 years, or in decimals,

the synodical period = ... 11.432 years.
11.110 = Wolf's period.
± .307 = acknowledged uncertainty = . . 11.417 years.

By taking the plus sign the difference is . . 0.015 years, or 5½ days.

Now both from observation and theory we gather that the epoch of minimum sun spots is more definitely determined, and, therefore, more reliable, than the maximum epoch; but from the researches of Prof. Fritz, the actual mean period derived from all the minima in the present century up to the last minimum (1879) is 11.4 years; only 0.03 years (11 days) less than our theory gives.

The close correspondence of these figures ought to go far to reconcile us to the retrograde motion of the new planet, and with a direct motion no reconciliation can be effected by any mass and distance given to another planet. This correspondence is fully shown on our Fig. 24, where the reader will find the relation of the Wolf numbers graphically compared by the appropriate curves, and also the want of correspondence between the Wolf curve and the curve deduced from the four great planets alone. The difference is an emphatic endorsement of planet VIII, with a retrograde motion.

While there can be but little doubt as to the existence of a planet or planets exterior to Neptune, it is possible that the same effect might be produced by two planets whose longitudes are, and have been, for some time, such as to produce the same effect as one in the position we have assigned—the one we have designated as Planet VIII. In such a case, the united masses must be much diminished, as one of the two would probably be at a much greater distance. If, however, there be but one at a greater distance than we have located it, an interme-

diate belt of ultra Neptunian asteroids might fill the gap, and by their number neutralize their own mechanical action in interfering with the position of the centre of gravity of the system. In such a case the chances of discovery would be very much diminished from increase of distance, and from smaller mass, while small planets, like asteroids, would not stand the shadow of a chance for discovery. But in any case of an ultra Neptunian planet it is imperatively required that the motion should be retrograde. No argument can be derived from the masses of comets, as they are confessedly insignificant and their numbers, indiscriminately distributed around the circle, will neutralize their effects. Still they might account for small outstanding discrepancies between the facts and the theory, which time will perhaps develop.

Prof. Forbes some time since (vid. Dun Echt Circular, 1880, April 29th, in Astronomical Register of June, 1880) announced his belief that a planet existed outside of Neptune in R.A. 11h. 40m. at a distance of 100 times the earth's distance; its period, of course, being a thousand years.

Now from the evidence on which this belief was founded, its existence could evidently not be reconciled with the motion of a direct planet, unless its position were considered almost stationary, and the bold resort to retrograde motion would be regarded as utterly out of the question. If the problem were attacked on the hypothesis of a retrograde planet, this great distance and period would not be necessary. But there is one objection against prolonging the period of a retrograde planet beyond the limits assigned it—the synodical period of the planet, as compared with Jupiter, would be less in accordance with Dr. Wolf's sun-spot numbers, unless the difference were trifling.

In order to assist those to whom this conception of the sun being at all dependent on the motions of the planets for his light and heat and all the other evidences of motions which his surface presents, is at first obscure, we

have prepared a chart (Fig. 22) on which the position of the centre of gravity of the solar system is designated by the two terminal figures for the first of January of each year in the nineteenth century, taken from column three of our Table IV. of polar co-ordinates, etc. This table gives the figures computed for both distance and longitude of the four great planets—namely, Jupiter, Saturn, Uranus and Neptune, and also for five great planets in columns four and five.

It is an accurate synopsis of the state of the system from 1783 to 1904, taking account of all inequalities (even the great inequality of Jupiter and Saturn) for these four planets, with the exception of those arising from inclination of orbits, and ignoring, altogether, the effect of the four minor planets, Mercury, Venus, Earth, and Mars.

In the chart, the shaded circle represents the sun, and its radius is the unit of measure of the tables, its centre being the origin. Necessary calls upon his time and failing health had caused the author to postpone addressing himself to this work year after year, yet feeling its importance, he suggested it at the general meeting of the American Association for the Advancement of Science, and offered a resolution which appears on page 385 of the Nashville Proceedings, and will be found in the Appendix, Note F.

On another chart (Fig. 23) will be seen the effects of an interpolation of our Planet VIII., with mass $\frac{1}{7\,\mathfrak{E}\,0\,0}$ and distance 47. In this figure, each year from 1783 to 1904 is designated by a dot, and only every tenth year written out, but as the curve is continuous it will be easy to follow it, and compare the distances from the centre with the polar co-ordinates of our Table III. These are found in the columns marked R', and the longitudes in the columns marked V'. As in the previous diagram of polar co-ordinates, the radius of the sun is the unit of measure, and its centre the origin; but the scale is taken twice as large as in Fig. 22.

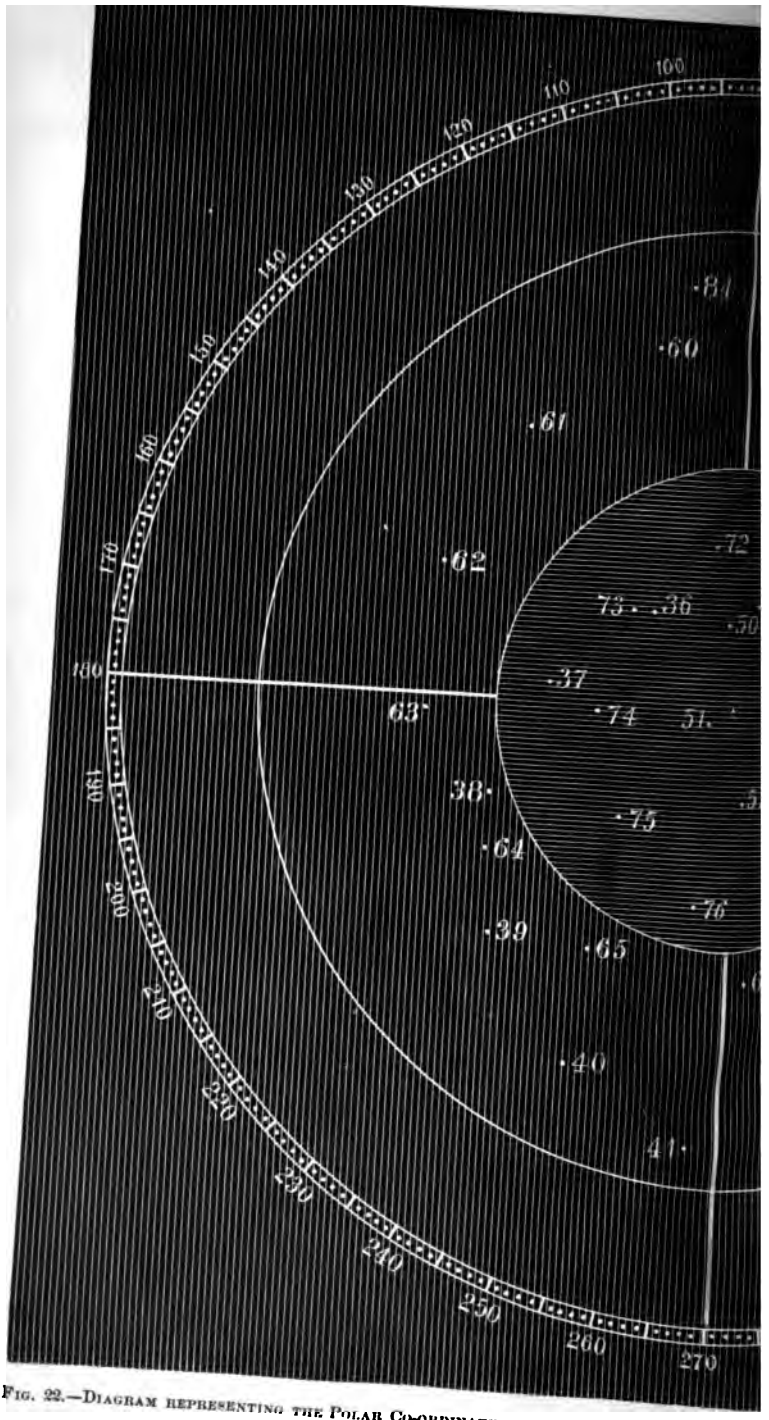
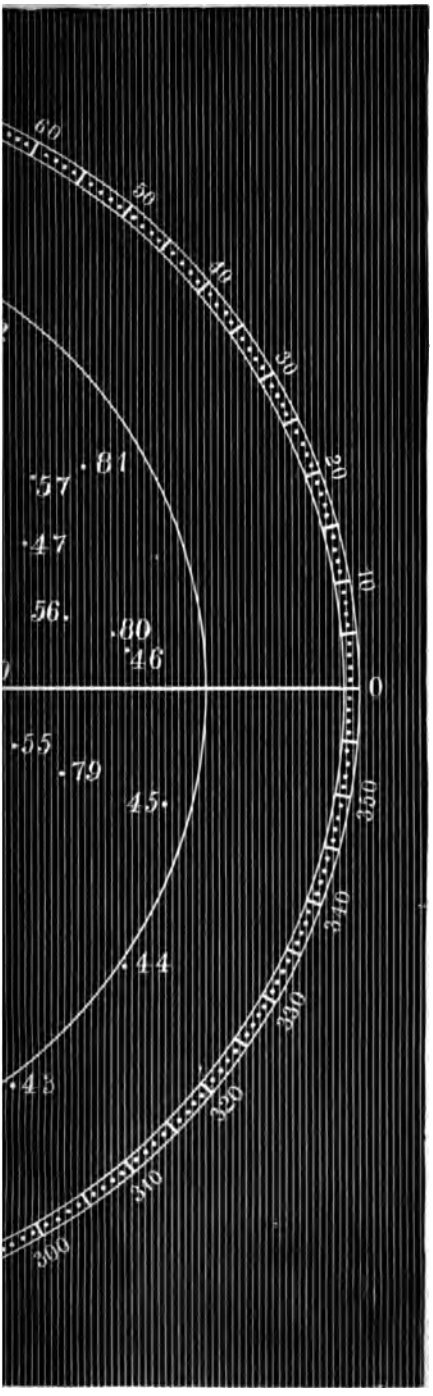


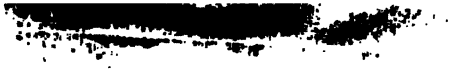
FIG. 22.—DIAGRAM REPRESENTING THE POLAR CO-ORDINATES OF THE CENTRE OF GRAVITY



THE 1ST OF JANUARY OF THE YEARS DESIGNATED.

EXPLANATION.

The dots indicate the position of the centre of gravity of the solar system on the 1st of January for the years designated by the last two figures of the century. To avoid confusion, the time is limited to fifty years. The small circle represents the sun. The radius of the second circle is equal to two semi-diameters of the sun, and the inner line of the graduated circle is equal to two and a half semi-diameters. The distances of the centre of gravity are derived from Jupiter, Saturn, Uranus, and Neptune only, and the longitudes are computed for the mean equinox of 1850, for which see Table IV., columns 2 and 3.



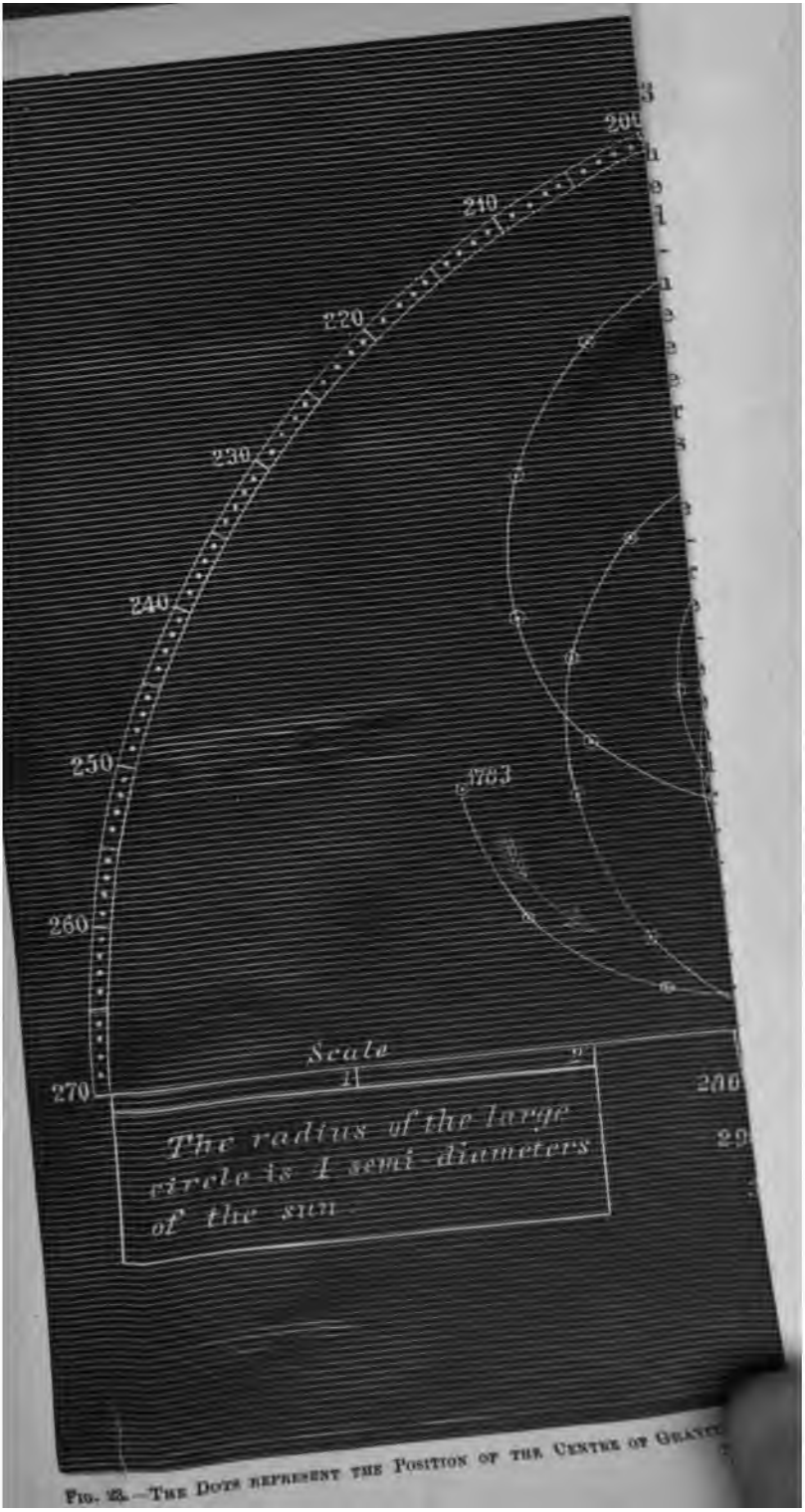


FIG. 23.—THE DOTS REPRESENT THE POSITION OF THE CENTRE OF GRAVITY

In view of the facilities placed within the readers' reach by the charts and tables, it is unnecessary to dwell on the undoubted fact that the planets do carry the sun around thecentre of gravity by their orbit motions. For convenience of reference we shall, however, regard the sun as *stationary*, and the centre of gravity in motion. We must now discuss the consequences of this motion in the ethereal medium, such as we have argued constitutes the bond of union between the various members of the solar system, and invests the sun itself with its tremendous power for good or evil, according to circumstances.

Briefly recapitulating our leading postulate—that the rotation of a material fluid, having inertia without ponderosity, necessarily rarefies the inner parts of the solar vortex, and that this centrifugal tendency is co-extensive with the utmost limits of the system, and begets an inward polar or axial current which is never able to restore the derangement of the equilibrium, on account of the preponderating tendency of *all* the matter in the system to recede from the axis; it follows that the sun is carried from *near* the axis, where for the reasons given in "Our theory of the corona," we infer the density (electric intensity) is greatest, to a distance of even three semi-diameters where it is much less. Alternately the whole sun is positively and negatively electrified as compared with the surrounding space, and there is an outward or an inward rush of the medium, according to the greater or less intensity of the medium pervading its gaseous body. The sun is never still, its distance is continually varying, and there is a constant ebb and flow, or rather *relaxation* in the equatorial ebb of the ethereal tide, daily and annually; the daily tide of 25½ of our days being superposed on the annual tide of 11.4 of our years. By this ordinary outflow of the ether, portions of the true atmosphere of the sun are carried upwards, in widely separated localities, and rendered visible by cooling at an elevation of from 3,000 to 6,000 miles above the visible

limb. This is the chromosphere, which is *not* an atmosphere, any more than our clouds of visible vapor would constitute an atmosphere to the earth, if capable of preserving their form after the atmosphere was removed. When this ethereal tide becomes more violent, such chromospheric clouds are carried above their usual level with electric velocity, and are seen as gigantic protuberances rendered visible by condensation in the *comparatively* cold, outside polar current; but they are not eruptions from the interior of the sun after the manner of our volcanoes.

There is every probability that space is pervaded by detached atoms and particles of planetary dust, whose influence is felt in extinguishing a certain percentage of star light, and, if so, the polar currents of the stellar vortices come down "loaded perhaps with the actual materials of the tails of millions of these bodies" (comets), of which they have been stripped in their successive perihelion passages," which, Sir John Herschel conjectured, might be the nature of the zodiacal light; only, he thought that this was the denser part of the medium of space condensing around the sun, instead of scattered dust suspended in that medium.

Now, if we follow one of these particles along its hyperbolic orbit due to the composition of the repulsive and attractive forces acting upon it, we see that the law of the force is not inversely as the squares of the distances. If we designate this attractive force by G and g, and distances by D, and d, by ignoring expulsion, and noting the greatest distance and force, in capitals

$$G : g :: d^2 : D^2;$$

but if we recognize such a force we have a different law for G and g before perihelion, and a still different law after perihelion. In other words

$$G : g :: d^{2+x} : D^{2+x}$$

before perihelion and

$$G : g :: d^{2-x} : D^{2-x}$$

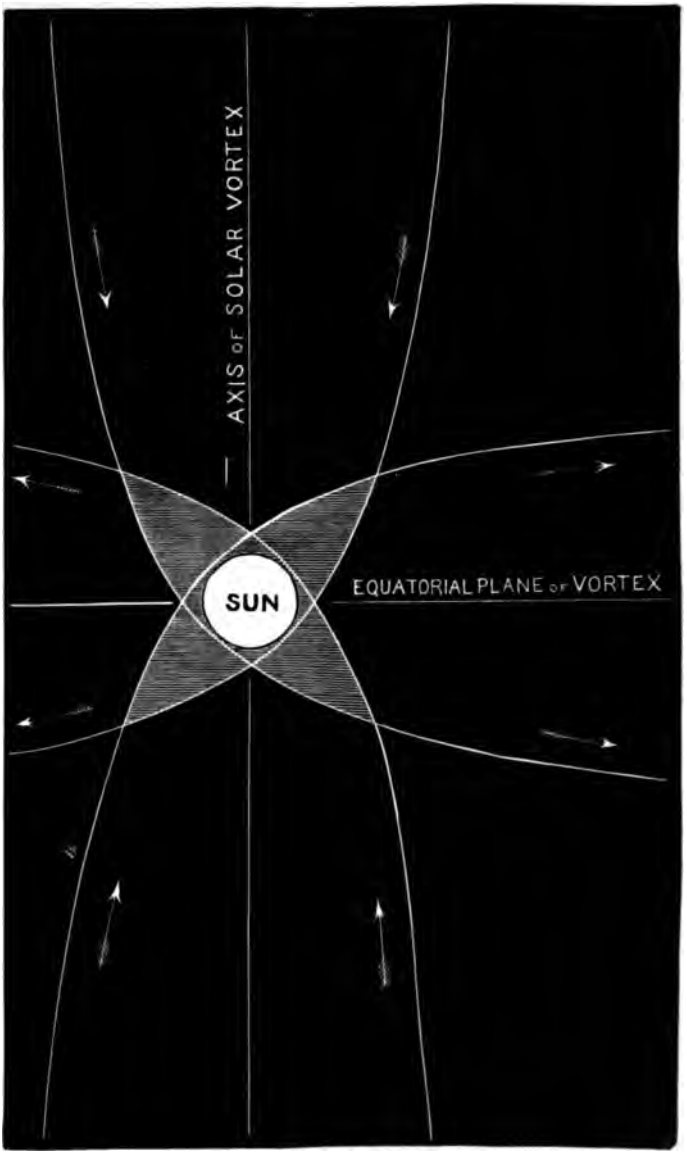


FIG. 21.—SHOWING THE POLAR AND EQUATORIAL CURRENTS OF THE ETHEREAL MEDIUM AROUND THE SUN.

after perihelion, where x is the fractional exponent of a force to be compounded with the central force in terms of the distances, either directly or inversely.

In the above diagram PP' represent the axis of the vortex, and S the sun. Let the arrows 1, 2, 3 and 4 be the paths traversed by four such particles in descending to the sun in hyperbolic orbits, having the sun in the focus. This presupposes they have no spiral motion around the axis, which cannot be true; still, there no doubt is an approximate conformity to motion in a conic section, and yet sufficient velocity in the spiral to neutralize a part of this motion, and thus, it may be reasonably assumed, they are retained in the sun's neighborhood for a longer or shorter period dependent on their densities to contribute to the general visibility of the solar corona and zodiacal light, without the necessity of resorting to meteors flocking inwards along the *equatorial* plane, or to matter ejected from the sun to distances, and with velocities which would preclude any future return.

We have been particular in indicating the course of the ethereal medium from its entrance into the interior of the solar vortex, and the cause of its greater visibility along the equatorial plane, arising from the fact that matter, which, diffused through the ether, approaches the sun under the united action of the impelling influence of the ether and the accelerating force of gravitation, passes outward with greatly diminished velocity, and thus becomes an obstruction to the more rapidly moving ether, and hence, the light in the corona and zodiacal light. This is analogous to the light of the terrestrial aurora, due to the rapid streams of the electric medium passing through the highly attenuated layers of the earth's upper atmosphere, even of that portion which fails to *reflect* light. It does not, however, follow that light may not be reflected from the particles whose resistance to the ether is the principal source of the light of the corona and of the zodiacal light.

The shaded petals of our coronal rose in the above diagram, by rotation, would mark out a solid which may be considered the denser portions of the radiated and synclinal structures which have been so often observed and figured in drawings of the corona. Then there would be a polar depression in which no light would appear, and the axis of the principal cones of light would be 45° from the axis of the corona; but if, as no doubt is the fact, the axes both of the sun and the corona are inclined to the ecliptic, it will only be when the longitude of the sun corresponds with that of the nodes in 74° and 254°, that is, early in June and December, that the apparent polar rays of the corona will be shortest. But it is evident that, in no position can the corona be seen denuded of a polar fringe, although it is extremely probable that there is no such appendage to that part of the sun, except in appearance—the result of perspective.

The above figure represents the axis of the sun as coincident with the axis of the vortex, but this can scarcely ever occur exactly. In 1822, the centres of the sun and vortex came nearer to coincidence than at any other time during the century. Whether the seasons responded is unknown to the author; but eleven years before, in 1811, the comet vintage and harvest marked the minimum of spots historically. Unfortunately we have no eclipse observations describing the corona for that year.

When the sun is very eccentrically placed, it is not out of the sphere of action of the polar current. The curve we have drawn for a single particle, sweeping past the sun in one plane, is appropriate for every plane and for long distances, outside and inside the sun, and it is satisfactory to find such a difference between the coronas of the maximum and minimum sun-spot epochs, as to have forced recognition. At a minimum epoch the corona extends equatorially far more than axially, and as everything is symmetrical, there will be greater regularity of form. Now place the sun eccentrically by a whole di-

ameter, there can be no such equatorial extension or regularity of form; but every evidence of cross currents and chaotic movements such as a maximum spot corona has been so often observed to exhibit. We also see a reason in the paths marked out for the general quadrangular figure of the corona.

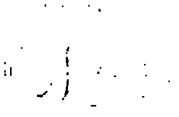
If it be objected that, according to this view, the inrushing ether is made to curve *around* the sun as if ponderable, our answer is that we only contend that this would be the natural course of particles of *planetary* matter, and where these are, there will the motion of the ether produce the necessary visibility without resorting to reflection.

But whatever particular curve the ethereal current follows down the axis, there must be great intermingling and innumerable eddies in close proximity to the sun. We have been digressing and must return, merely remarking that those long streamers of which the outer corona is principally composed, only differ from the more condensed and luminous appendages of the sun in being caused by the rush of the ethereal currents through matter, which is far more diffused and much farther removed from the solar surface than the clouds of solar vapors which have been raised by electric convection from the surface, and return to it again. The frequent curvature of these streamers at their extremities show unmistakably the numerous cross currents of which we have just spoken. We now return to the solar spots.

Changes on such a stupendous scale, as are in operation on the sun, cannot be accomplished in such an orderly way as to exhibit no anomalies. The effect is rather an average effect of positive and negative action than of steady progress in one direction, and a contrary impulse of the same uniform character. Suppose we have a portion of the sun's equatorial regions turned towards the central axis. In this situation the surrounding ether is denser than on the opposite side of the sun; but, by a semi-

rotation in 12.75 days, it is carried 800,000 miles further from the axis, when a derangement of the equilibrium of the internal ether and an uprush takes place from greater and greater depths according to the intensity of the force. This carries up from those depths the gaseous elements of the sun's interior, which, thus, are suddenly relieved from the enormous pressure of those depths. The consequence is, they are rapidly expanded, and by the rapidity of their expansion lose in temperature, until when they arrive at the surface of the photosphere they are so cooled as to condense into visible vapors—into vast accumulations of clouds piled above the photosphere, very similar in form to a lunar crater, with but a slightly depressed centre and gently sloping external walls. This form is prescribed by the nature of the force to which a spot owes its origin. The escaping ether carries up by convection the gases which obstruct its passage. These arrive at the surface with the motion impressed upon them, and boil up as the waters of a spring, and would form above the photosphere a convexity whose centre would be elevated above the sides, and thus no umbra of any magnitude would be formed, however extensive the penumbra might be. But the ethereal current, besides the rectilinear motion upward or downward, *must* partake of the spiral motion of the *great* vortex. In the northern hemisphere of the sun this motion is from right to left when downward, as on the earth—for if we watch our road-side whirlwinds, where no obstruction is near, we find that these obey the general current of the terra-lunar vortex, and revolve from right to left. By this spiral motion the welling stream of condensed vapors is forced to assume the crater-like form of a lunar mountain, in which the outer ridge is the highest—the crest of the wave from whence the vapors flow downward to form the penumbra by reflected light.

There is nothing in this theory akin to Faye's, or Secchi's theory of 1868, which resorts to internal gases



bursting outward, and thus opening a passage through the photosphere, revealing to us the feebly radiating gaseous centre of the sun, as dark by contrast. Neither is it obnoxious to the spectroscopic objection to those theories, for the spectrum of such an umbra is that of much cooler vapors than exist in the photosphere. If Faye is right, and the emission of light and heat the result of the transfer of gas from the lower regions of the sun to the surface, then our theory of the *modus agendi* is wrong, although this would not subvert the foundation—for we contend that diminution of pressure would have a contrary effect. As for Secchi's idea, that a spot is like a hole in the photosphere caused by its temperature being raised so much by the hotter gases of the interior as to become invisible, it is rather extravagant. In fact, a spot, according to this view, would be caused by *burning a hole through the photosphere by the same process on which Faye depends for maintaining the existence of the photosphere.*

There are other theories based upon downward currents—for no doubt there are downward *ethereal* currents—but this could not have the effect of cooling the photosphere. A transfer of gas to a lower level would increase its temperature by compression, and therefore could not render an invisible gas more visible.

When we represent a spot as at a higher level than the photosphere, we mean that the umbra presents a convex surface, when seen in profile, above the level of the photosphere. A solar spot is something like the top of one of our great thunder heads seen from above, projecting from a surface of level stratus, which we will suppose (for the sake of the illustration) to receive its light from below. That light may be further supposed to be strong enough to penetrate through the stratus but not through the depths of the thunder head. This would therefore show a black centre (the umbra), with sloping sides above the enlightened stratus, and these sides, although mostly impervious to the light from below, may not be entirely

so; yet being more or less elevated above the general level, would receive light from the surrounding stratus, and so reflect a portion of it to constitute the penumbra. The penumbra of a spot is, as a whole, therefore, not as high as the umbra, but yet more or less elevated above the photosphere. But neither penumbra nor umbra are of such vast vertical magnitude as the protuberances. If this be an appropriate similitude, the margin of the penumbra in contact with the umbra ought to show the brightest, as it, not only by its greater elevation, receives more light from the photosphere, but also suffers less from absorption in passing through the solar atmosphere. Now, still adhering to the analogy, our great thunder heads are flat or anvil topped, and in the case supposed where the only light comes from a stratus illuminated from below at a far lower level, their tops are not exposed to the light at all, and so with the solar spots, which, being composed of opaque and heavy vapors invisible from the photosphere, can neither transmit, generate, nor reflect light, although there may be scattered points and spurs and floating clouds which are sufficiently elevated above the bounding crater-like ridge, where the penumbra begins, to become visible by reflection, but the umbra where level or concave can reflect no light. What it emits is its own inherent light varying with the temperature unless it be feebly enlightened by the corona or by neighboring protuberances which may give a filamentous aspect to portions of it. In this connection the faint gossamer veil depicted in the cut on page 110 (Fig. 16) is instructive. It was a mere film—the footprints, as it were, of a faculous bridge.

But the analogy may be carried still further: for the thunder head begins to sink to a lower level as its energy is dissipated and becomes absorbed into the surrounding stratus, which last, also, finally disappears, and the disturbance is over. So it is on the sun: the umbra begins to sink or flatten out, and the penumbra to get fainter and

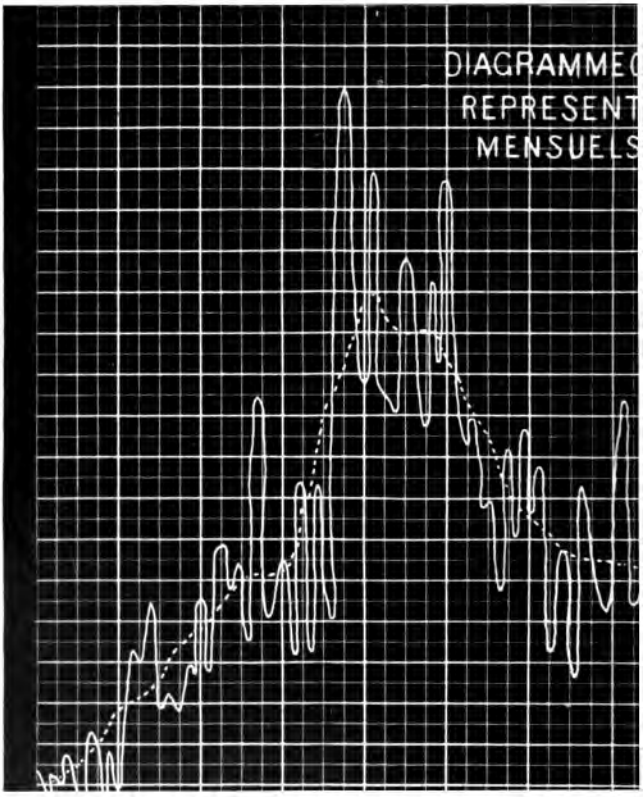
lose its radiated structure, and become more irregular in outline, throwing off, as it were, its dependence on the umbra, until it breaks into patches, and gradually fades away by the absorption of the umbral gases into the photosphere.

Observation also decides that the penumbra is darker at its outside margin than elsewhere, which can also be explained; for 1st. This margin is the lowest and therefore suffers most from absorption; and 2d. Being at the bottom, it receives less of the light of the photosphere than the more elevated portions. There is also another peculiarity in the penumbra of a spot which receives its explanation in the same way. Where the penumbra projects into the umbra there is often a corresponding projection into the photosphere. Does not this further confirm our theory? Usually, the more extended the talus, the higher is the escarpment, and so we may infer the side of the umbra where these spurs project is the highest, and, generally, the dimensions of the umbra, in a regularly formed spot, will correspond with the penumbra, being roughly about $\frac{1}{3}$ of the diameter of the whole.

But it may be objected that the process we have outlined depends on the rotation of the sun and not on the greater or less distance of the centre of gravity from the centre of the sun. To this it may be answered that both causes are in operation and show their influence unmistakably. We have stated on a previous page that there are what may be called ethereal tides produced by the planets, but differing from our ocean tides in being due to their mechanical action instead of to their gravitating force. The daily tides (a day on the sun is twenty-five and a half of our days) are due to the alternate presentation of every solar longitude to the axis of the solar vortex in which the centre of gravity of the system is situated and to the denser ether on that side of the heavens. As we have before remarked, this constitutes a change for solar tropical latitudes of over 800,000 miles in twelve and

three-quarter days. What evidence have we that in this short period there is a subordinate fluctuation of solar spots from maximum to minimum and back again to maximum? On Dr. Wolf's chart the curve of relative numbers is drawn, representing the great annual tides from 1831 to 1875 (the year of the sun is the time the sun takes to go around his orbit), the average being, according to Wolf's limits, 11.417 years, but according to our theory 11.432 years, and, superposed upon it, the curves representing the minor fluctuations which do not at first sight appear to follow any law. In 44 years, covered by the chart, there are 180 maximum epochs, small and great. Now, as we estimate the average rotation of the sun at 847′ per day, giving a full rotation in 25¼ days and giving the maximum spot latitude for the average latitude of rotation; by dividing 44 years by 180 we get for the average interval between these small maxima 89¼ days, or seven of the average semi-rotations of 12.75 days. As four periods of 89¼ days nearly amounts to a tropical year and the axis of the great vortex is on the average pretty stationary, we are in conjunction with the axis every fourth period during which the sun has rotated fourteen times, thus presenting the same meridian of the sun to the observer, under the same circumstances as respects its electric condition. Of course the synodical period will bring the same meridian every 27.4 days estimating the rotation for the same solar latitude, but not under the same electric conditions. The varying rotation periods of different latitudes will, it may be presumed, always throw insuperable difficulties in the way of reconciling the several periods except for short intervals; yet it is in this path we must walk, if we would subject all the fluctuations of the spot period to some rational standard of periodicity.

Unfortunately, the full benefit of Dr. Wolf's relative monthly numbers cannot be obtained for such comparison. Those observations never contemplated that the



DIAGRAMME
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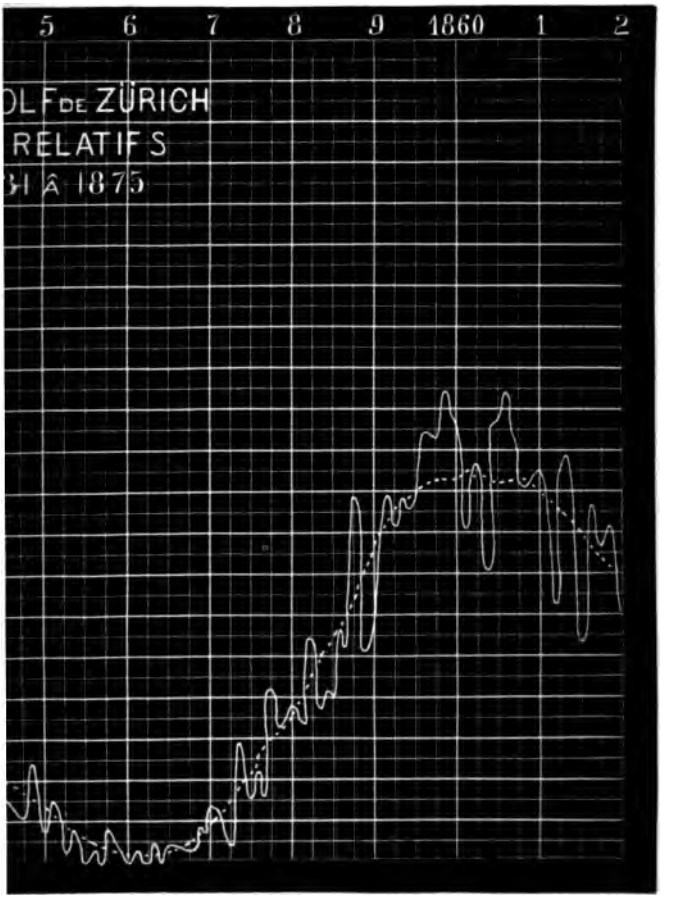


II., Exhibiting the Character of Doct. R. Wolf's Curve of Solar Spot

sidereal period of the sun's average rotation could throw any light on the subject; nor was it surmised that the heliocentric longitude of the centre of gravity, as well as that of the earth, could figure in the question of the solar spots.

The truth is that for the verification or refutation of any special theory, observations must be specially made with reference to the principles of such theory; but there is little chance of such being made as long as such theory is pronounced nonsensical, before its principles are examined.

Not having access to such records as are kept at Greenwich and elsewhere, the author can only now present the independent testimony of Prof. Tacchini for the first seven months of 1881 on this particular point, who, after reviewing the series, finds that in those seven months there are several strongly marked periods of great sun-spot frequency, often separated by an interval of *half a rotation* of the sun (vide "Observatory," Oct., 1881).

From the summary of Prof. Tacchini's report given below, it will be seen that more than half the intervals have *even* divisors, and, therefore, it must also indicate a full rotation period as well as a half rotation, the half rotation arising from disturbed portions of the solar surface 180° apart, exposed alternately to the negative outside and the positive axis of the solar vortex, and, as we shall see by and by, this fact is abundantly confirmed by Dr. Wolf's observations, and, as we have before remarked, by the approximate commensurability of the sun's synodical rotation with his period of 7.65 months. According to that summary, given on next page, there results an average of thirteen days for a half rotation, which would answer either the sidereal rotation or the synodical rotation. In order to understand why, from different dates, there should be an interval of half a rotation to a second maximum, while from another date a half rotation will give an intermediate maximum, it is

necessary to examine the mode of action we have suggested.

Prof. Tacchini's report Comptes Rendu. Vol. XCIII, No. 8:

MAX. OBSERVED.	INTERVAL IN DAYS AND PERIODS.							DAYS.
January 17–21...	Jan. 17	to	March 9	= 51	days,	divided	by 4	= 12.7
	Mar. 9	"	April 2	= 24	"	"	" 2	= 12.
March 9–20.....	Mar. 20	"	April 2	=				= 13.
	Mar. 20	"	April 16	= 27	"	"	" 2	= 13.5
April 2–9.....	Apr. 2	"	April 16	=				= 14.
April 16–25.....	Apr. 9	"	May 5	= 26	"	"	" 2	= 13.
May 5–9	Apr. 25	"	May 9	=				= 14.
May 23–31.....	May 5	"	May 31	= 26	"	"	" 2	= 13.
	May 5	"	June 12	= 37	"	"	" 3	= 12.3
June 12–18.....	May 9	"	June 18	= 40	"	"	" 3	= 13.3
	May 23	"	June 18	= 26	"	"	" 2	= 13.
June 25.....	May 31	"	June 25	= 25	"	"	" 2	= 12.5
July 10.....	June 12	"	Aug. 4	= 53	"	"	" 4	= 13.3
August 4.....	June 25	"	Aug. 4	= 40	"	"	" 3	= 13.3
*	Aug. 4	"	Aug. 30	= 26	"	"	" 2	= 13.

* This last is from the Greenwich Photographs.

By rotation a portion of the solar surface permeated by the denser ether of the inner space is carried from the axis. This dense ether, which pervades all that part of the sun to the lowest depths, tends more and more rapidly to escape as it recedes from the axis, until enabled to establish a vent or channel through the photosphere, it carries up with it the gaseous elements of the sun, which, by continual and rapid expansion by diminished pressure, come to the surface of the photosphere as the smoke of a furnace. Now, ordinarily, the pressure will be relieved after continuing in existence a few days, and the spot may be dissipated or appear to be dissipated in the time of half a rotation, for the reason that the conditions of relative external and internal pressure will be changed; but another half rotation will bring back the first conditions and the *same region* which, perhaps, had only been half relieved, or having been again subsequently recharged over and above contiguous parts by peculiari-

ties of the elementary components, will again exhibit, near the same place, the same evidences of maximum unrest as at first. And this, not only for a second time, but, perhaps, for a third or fourth semi-rotation, until internal commotions have changed the field of action to another part of the surface.

Repetitions of this kind have induced some physicists to regard the sun as a solid globe, or at least solid at some moderate depth below the surface, and that spots are, merely, the cloud-capped volcanoes through which the interior fires find vent. If such views were not utterly untenable, they are at least unnecessary, as the facts, which they seek to explain, are better referred to the causes herein advanced.

There are many phenomena which can only be explained by the rotation of the sun. It has been noticed that whenever any great change occurs in the leading spot of a group, showing great activity in the producing cause, it often seems to advance westward with giant strides, leaving a trail of débris behind. The velocity with which this is accomplished ought to make us distrustful of our eyes, if it be necessary to admit the transfer of a large spot bodily with such amazing rapidity. But it is not necessary; for it is only an occasional feature which may be explained otherwise. Suppose a spot, in the *spot latitude*, is receding from the central axis. A spot near the sun's equator, when in quadrature with the axis, recedes from that axis at the rate of about 76 miles per minute by rotation alone, and the general tendency then is for those parts in advance of the spot, to feel the diminution of outside pressure so as to elongate the spot westwardly by an uprising, and curtail it eastwardly by a subsidence. But such curtailment is not so complete as to obliterate it. Its progress is strewn with wreckage (if we may use the term), which is left comparatively motionless behind. In some cases the spot may merely divide, or appear to divide, by the western half alone being elongated by a

steady protrusion from below, while the other half is left behind unchanged. This, however, can only be verified by micrometric measures having the decision of this point specially in view, so as to compare the rate of the advance movement in different positions of the spots, with reference to the axis of the vortex. Generally such exhibitions ought to occur where the displacement is large and the spot is receding from the axis, for it is owing to change of density with change of position, when this peculiar effect we have described can be produced.

If the sun be considered stationary in the *centre* of the solar vortex, no matter what the law of density of the ether at different distances might be, there could be no disturbance of its equilibrium by the rotation or from varying density. This is the position of rest or inaction in the solar system, as the position of maximum displacement is the one of great activity and unrest, which develops the spots in the greatest number and magnitude, and all other solar phenomena. But those great convulsions are not confined to the sun; the earth (and by parity of reasoning all the other planets of the system) is disturbed by magnetic storms, earthquakes, cyclones, floods and general distress caused by abnormal activity in the elements. (See Note I.)

Whether exemption from these evils attends the minimum epoch, can only be doubtfully inferred from a few scattered dates, but 1811—the year of the great comet—was a minimum year connecting which, we may remark that, for many years, the comet wine was considered the *ne plus ultra* of the best. Whether the same cause is equally potent at every similar minimum of sun spots, is difficult to decide, as the effect may vary with localities; but, certainly, the evidences of great commotion in the elements are not wanting during the present maximum (1883), and it may be considered as certain that there is a greater electrical excitement—more thunder and light-

ning (and consequently heavier local rainfalls) during a period of maximum sun spots than at the minimum.

Next, there is this great observed fact fully explained by our theory: neither spots nor eruptive prominences (prominences of great elevation are here meant) are found much above latitude 40°, and then so rarely that only a very few have been recorded. The most fertile latitude is between 10° and 30°. This would indicate that the rotation of the sun is an important factor in producing the spots in connection with displacement, but there are other agents at work in producing the spots, which are caused by the displacement and receive a great accession of force from rotation. These are the true *electrical vortices* caused by the displacement due to the planets, as our own electrical vortices are caused by the displacement due to the moon.

The sun being displaced from the centre of the solar vortex causes an obstruction to the circular current; for it must be conceded that planetary matter does resist the passage of the ether more or less. Now, if, in the first place, we locate the sun exactly in the centre, the polar current (the central vortex) will be over the poles of the sun. Now displace the sun a little and it is no longer concentric, but lateral vortices will be formed, yet not very distant from the central vortex. Displace the sun still more, and the distances (the radii of their little orbits) will also be increased, and, sensibly, in the same ratio as the displacement of the central vortex. On the earth, the radii of all the seven vortex orbits vary but little, being, as appears from the table of elements, about $\frac{1}{10}$ or $\frac{2}{3}$ of the semi-diameter of the earth, varying with the moon's parallax; but they can never become equal to it, on account of the mass of the moon being only equal to $\frac{1}{81}$ part of the mass of the earth. With the sun it is different—the displacement of his centre being sometimes as now (1883) as much as three solar semi-diameters from the centre of gravity. At such times the whole surface

of the sun is forced clear of the axis, and therefore there are only lateral vortices formed very near the equator. In the most prolific latitudes, say 10° or 12°, the radii of these lateral vortices (the cosines of the latitudes) are from $\frac{9}{10}\frac{7}{0}$ to $\frac{9}{10}\frac{9}{0}$ of the solar radius.

We have already alluded to the erroneous inference into which we were led thirty years ago by attaching too much importance to the action of the central vortex, which, at a great displacement, does not fall upon the solar surface. But, on the other hand, the lateral vortices are increased in energy by a great displacement, and no doubt the solar spots would be greatest at the equator but for a reason we shall presently explain. In the mean time it is easy to see that the radii of the orbits of the lateral vortices cannot increase continually, as the displacement or central radius increases; for, even if we were to make that distance infinite, and place, for experiment, an obstructing globe in a perfectly rectilinear current of water (which would be equivalent to making the distance from the centre infinite) we should still have eddies, as around the bowlder in the brook, whose axes would fall on the obstructing body. No doubt the eddies in a gaseous fluid will behave somewhat different, but in a general way the analogy may be trusted. As the elongation of the sun then increases by planetary displacement, the spots, from the causes named, increase, beginning in a comparatively high latitude—say 35° perhaps. In a year or two the displacement becomes greater and the spots increase in numbers, and appear in a lower latitude until the maximum is reached, when they begin to wane, reaching gradually toward the equator, until past the minimum, when they disappear, and the same process is repeated but not always to the same degree, and not always proportional to the solar displacement. It is needless to say that this feature has also been observed; but the general tendency of the spots is to drift toward the equator, and their *formation* is at a higher latitude after minimum is passed.

But we will be more explicit, as this fact, combined with Wolf's observed differences in the intervals from minima to maxima, when compared with the intervals from maxima to minima, will, when explained in accordance with the theory, go far to convince every unprejudiced mind that a key which opens so many secret chambers must necessarily be the true one.

We presume that the reputation of M. Spoerer as an observer, will scarcely be called in question on this particular point, and therefore we may be pardoned for attaching some importance to his testimony, as it relates to facts which an ordinary observer would not be likely to notice; yet even he failed in reducing it to rule.

Early last year, M. Faye presented to the Academy of Sciences at Paris a memoir from M. Spoerer, in which he gives the results of long observation, determining the following facts, as noticed in the "Observatory" of March, 1882. "The chief display of spots is confined between latitudes 6° and 35°. The spots after the period of minimum is passed seek a high latitude; the latitude then diminishes while the spots increase, until the centre of disturbance is at latitude 18°, when the spot activity is at its maximum. After passing this point, the centre of activity continually approaches the equator, the spotted area at the same time growing continually smaller, until the spots entirely disappear at about 5° or 6° of latitude." Here we have a practical test of the truth of our theory. Let the reader recall what we have stated about the origin of the lateral vortices, and bear in mind that the minimum corresponds to the smallest displacement of the sun from the centre of gravity of the system. As it is upon our own globe so it is upon the sun. When the moon is at her perigee the radii of the several vortices are then the shortest, reaching into higher latitudes at their extreme frigid limits in both hemispheres, and not attaining to such proximity to the equator at their torrid limits. At the apogee everything is reversed; but this

is all gone through in one sidereal period of the moon. On the sun, his sidereal year varies, but averages, as we have shown, 11.4 of our tropical years. The lateral vortices on the sun begin to make themselves felt when the radii of their orbits are about the same as their mean value on the earth or .707 = the cosine of 45°: but as the sun departs from the axis these radii extend.

Now the reason why, in receding back to the minimum distance, the spots disregard the routine observed before they attained the maximum, arises from another cause totally distinct. The sun is passing inward instead of outward. It is flood-tide upon the sun instead of ebb, as in the other case. In a word, it requires more energy to create a spot than before the maximum, and therefore the cosines of the higher latitudes fail to give the necessary difference between conjunction and opposition. That the flood-tide takes a longer time than the ebb is according to analogy, for the earth parts with its heat much faster than it absorbs it; so with this fact also. At the minimum distance the ethereal current is inward. By this current is not meant the radial stream, but that comparatively quiet ebb and flow of the outside ether, out of, and into, the body of the sun, according to the excess of external or internal pressure. As the sun increases its distance the spots become more numerous, subject to the subordinate influences which we have shown exaggerate or diminish the general activity of the solar surface. Meantime the radii of the orbits of the lateral vortices are enlarging, and the spots of course are found in the lower latitudes. When these radii exceed .95 of the solar semi-diameter = cos. lat. 18°, the axes of these lateral vortices being parallel to the central become so oblique as to produce less effect than before, and the spots begin to wane a little before the maximum distance is attained; when that distance begins to diminish, the sun, already relieved of some of its superabundant electricity, is continually getting into denser ether, which

still diminishes its internal pressure; thus it only takes 4½ years to reach the maximum from the preceding minimum, while it takes 6½ years from the maximum to reach the following minimum on the average. As the spots are caused by an upward flow, the development of the spots is *with the tide* before the maximum, but after the maximum is passed the outflow is against the tide, and therefore is retarded and obstructed, all which is adverse to the formation of spots (in high latitudes, especially, because the energy of the spot-forming force is determined, in a great degree, by the subordinate influence of the sun's rotation).

If the reader has ever visited a cotton-printing establishment, he must have seen the large drums, filled with wet calico, revolving with great speed for a brief period; but in that brief period the centrifugal force has expelled every drop of water and they are taken out dry. Let him then conceive the sun to be in rotation, saturated with a fluid which the central attraction does not restrain from escaping, and passing from a medium where the pressure is great to a similar medium where it is much less, which assists the escape of the imprisoned fluid. Now, let it pass in a state of diminished tension from a medium where the pressure is less to where it is greater, and it will occupy much longer time to disgorge. Hence the time is 4½ days from minimum to maximum, and 6½ days from maximum to minimum roughly. As there is no such difference in the exciting cause, the maximum sun-spot epoch observed may be set down, at least, at 1¼ years too soon at every maximum; which will reconcile the maxima of our computed curve with Wolf's observed curve.

Let us take the true interval between them.

Maxima to minima = 6 90 years.
Minima to maxima = 4.53 years.

11.43 years.

The computation gives 1884 as the next maximum

period, and between 1804 and 1884 are 80 years, or 7 periods; but $\frac{80}{7} = 11.43$ years, the very period our theory determines from the synodical period of Jupiter and Planet VIII.

Now, as the planets determine the period, the interval between minimum and maximum must be half of the whole or $\frac{11.43}{2} = 5.71$ and $5.71 - 4.5 =$ the excess of the computed over the observed interval $= 1.2$ years.

Beginning our comparison with Wolf's maximum of 1837.2 we have—

Dr. Wolf's Maxima.	Computed Maxima.
1837.2 + 1.2 = 1838.4	1838.7
1848.1 + 1.2 = 1849.3	1849.3
1860.1 + 1.2 = 1861.3	1861.0
1870.6 + 1.2 = 1871.8	1872.0
* 1882.4 + 1.2 = 1883.6	1883.8
	1896.0
	1907.3

* This last date is from the U. S. Signal Office.

But why should the spots be more abundant in latitudes from 10° to 20° and be altogether unknown at the equator?

If the spots were due solely to the atmospheric currents of the sun we might find an analogy here between our trade winds and the equatorial calms, or between the hurricane latitudes on the earth being limited to latitudes above 8° from the equator, but such a cause is inadequate on the sun for many reasons. The true explanation is found in that general circulation of the whole gaseous body of the sun ever crowding in overwhelming billows from the north pole to the equator, and being there met by a similar drift from the south pole, which renders the equatorial latitudes protuberant. The current then sets downward in a continual stream of ring vortices under the impelling power of the sun's rotation and against this

downward rush, which is perpetual and independent of every force but the centrifugal force, there can be no such adverse current of restoration as in higher latitudes. It is only the legitimate working out of the problem which we have before discussed.

But this does not interfere with the formation of chromospheric prominences at the equator, as we consider them, for the time being, as *equivalent* to imponderable elements carried up by the escaping electricity of the sun, although, not quite as energetically as in the latitudes of the spots.

We have only now to enter a little more into the process of disturbance caused by the lateral vortices. The chief characteristic of a vortex is, as we have had occasion to show, a rarefaction around an axis of motion in a fluid medium, generated by the tendency of matter to recede from that axis, under the influence of the centrifugal force of rotation. The eddies in the great solar vortex caused by the obstruction of the body of the sun to the circular current, are here called lateral vortices in contradistinction to the axis of the vortex which is called the Central, as we have already explained. It is assumed (justified by the analogy of the terra-lunar vortices) that the axes of the lateral vortices are parallel to the central axis. How many there may be, and whether the number may not vary with the amount of displacement, is something yet to be determined. On the surface of the earth there are five lateral vortices in each hemisphere, with two others, which jointly perform the office of the central, and therefore are called the Central and Bi-central. The rotation of the sun brings the surface under the several vortices once each average rotation of 25½ solar or civil days.

The course of the sun in its orbit from minimum to minimum is very irregular, and that orbit does not often pass around the centre of gravity of the system. By examining our Table III. we see that the average long-

itude of the centre of gravity (taking the centre of the sun as the origin) for the century between January, 1783, and January, 1883, is 175°, the mean equinox being that of 1850; but from 1783 to 1833, it was nearly 210°. Now this explains another feature of the sun spots. From September to January it has been observed that sun spots are more abundant than at other seasons. The longitude of the earth is in the first quadrant during October, November and December, or, in other words, the centre of gravity of the system is approximately in 180° greater heliocentric longitude than the earth, and, therefore, the visible hemisphere of the sun during that time is the one where the electric medium is least dense, thus the escaping ether exaggerates the effects of the lateral vortices, for both causes work harmoniously together. We see, therefore, that in such a position more spots ought to appear, *ceteris paribus*, than when the two longitudes do not differ materially.

But Dr. Wolf also finds a series of small undulations succeeding each other, at an average interval of 7.65 months, or 0.637 of a year = 229.5 days, which Sir John Herschel compares with Venus, whose period is 225 days, or the 0.616 of a year. This, he says, is a "coincidence, certainly, near enough to warrant some considerable suspicion of a physical connection." If 225 days is near enough to 229.5 days to warrant such an inference, when no physical cause can be assigned for the connection, how much greater claim to such an inference has a theory which *can* assign a physical cause for a connection between 25.5 days—the sun's average sidereal rotation—and Wolf's average interval of 229.5 days; for nine times 25.5 is equal to 229.5 exactly.

But let us examine Dr. Wolf's period of "small undulations" more particularly, and inquire why nine sidereal rotations of the sun should produce these "small undulations," when some other number of rotations makes no such differences. By referring to our Table III. in the

columns marked V' and R', we have the longitudes of the centre of gravity and the true radius vector of its orbit for the 1st of January from 1783 to 1904. Generally speaking, it is only when R' is very small, or at the epoch of the spot minimum, that there is any chance of the centre of gravity being included in the orbit of the sun. This is graphically exhibited in the chart (Fig. 23) at page 142, where the migrations of the sun are delineated by a continuous curve. We see from this that the greatest change of longitude occurs at the epoch of minimum, and that the sun does not always pass around the centre of gravity in the spot period of 11.43 years. If he did, $\frac{360°}{11.43 \text{ years}}$ would give the average annual motion in longitude $= 31\frac{1}{2}°$ per annum. To apply this to Dr. Wolf's period of 7.65 months would require exact details of times and circumstances, which are not given, so we must content ourselves with a general explanation. We have shown that nine sidereal rotation periods correspond exactly with the 7.65 month period, but in 7.65 months the earth is nearly on the opposite side of her orbit, and the side of the sun then presented is not the side which was observed seven months before; so that there is half a sidereal period difference, if referred to the sun. But if we take the average synodical period of 27 days, we get the very same side of the sun presented to us at the end of 229.5 days, or in $8\frac{1}{2}$ synodical periods of 27 days. For $8\frac{1}{2} \times 27$ is also equal to 229.5 days. This commensurability between the two periods is remarkable, and no doubt may have its influence in determining the period of "small undulations," if certain portions of the sun continue for any length of time in a state of fitful or spasmodic excitement, and we have the record (see Young's Sun, p. 118) of one spot, observed in 1840 and 1841, which lasted eighteen months. The complete history of this spot, showing its times of comparative activity and quiescence, would be instructive, for a gradual growth

and decay without violent changes in such a long-lived spot is inconsistent with the evidence offered by the spots of the present time.

This synodical period, however, is not the period which presents the sun to us under the same circumstances at the end of 229.5 days. If the axis of the vortex, or centre of gravity of the system were in conjunction with the earth as seen from the sun to-day, in 229.5 days it would be in opposition, and the sun, as seen from the earth, would present a different side. Now let us figure again. In 11 years (the approximate spot period) there are 4017.75 days, which divided by 229.5 gives 17.5, or in other words $17\frac{1}{2} \times 229.5 = 4016.25$ days, being only one whole day less than eleven years, and in this eleven years there are 315 *sidereal* semi-rotations of the sun. This being an *odd* number determines the synchronous coincidence of the following periods:

1st. Wolf's period of small undulations.
2d. Wolf's period of maximum spots.
3d. The sun's sidereal semi-rotation.
4th. The tropical year, and
5th. The $89\frac{1}{4}$ days of Wolf's minor maxima.

It is true that the average spot period is a little more than eleven years. Wolf only makes it 11.1 years, but that average period is never observed. The 46 epochs of maximum and minimum tabulated by him, do not exactly correspond to the average in a single instance during the whole interval from 1611 to the present time. It is, however, a fact of sufficient importance to be taken account of; and this question of the difference of longitude between the earth and the centre of gravity of the system and the distance of that centre, is all important in construing the varied aspects of the corona in total eclipses of the sun as well as of all other solar phenomena.

On reviewing our remarks we may, with confidence, assert that all the leading phenomena of the spots have been explained on mechanical and common-sense princi-

ples, and no violence done to the code of science; but we have more particularly examined the origin and causes of the different periods of maximum and minimum fluctuations in which the effects of the rotation of the sun perform such an important part; and, more especially, because it is the feature which of all others is regarded by physicists and astronomers as the most mysterious. We have also given in detail a satisfactory reason for the limitation of the spots to certain zones of latitude which is also regarded as a most important element of the general problem, for which no satisfactory reason had been assigned. In this discussion we have regarded the results of Dr. Wolf's labors as exhibited in Table I., with that respect to which they are entitled. Still, we cannot slavishly follow any authority unquestioned, and have, therefore, taken the liberty of suggesting why certain small discrepancies between his epochs of maximum and minimum and our deduced values of the resultant polar coordinates of the sun appear on our chart. (See the comparison a few pages back.)

In such a complicated question as Dr. Wolf attempted to solve, the difficulty he encountered in deciding on the right way of interpreting his records was great. If the actual number of spots in a given time was to rule, then the question would come up, why a few large spots should not be evidence of greater solar activity than a great number of small spots. If groups were to be taken, the actual area covered by spots might be greater in a small group than in a large one if the general area covered by the groups were to be taken into account. Then there is the question of the comparative number of observing hours as contrasted with the whole time between any given dates. For, of course, an observer could not be at his telescope all day, and spots often appear and disappear in a very brief time. The night is necessarily excluded, and even at best we can only observe one-half of the sun. Then there are cloudy days wherein the sun never shows

his face. Again, in compiling records from the numerous sources (seventy-five names are given) between 1610 and 1826—the time when the first systematic observations were made by Henry Schwabe—how general and capricious must the testimony have been, seeing that no one ever suspected that the phenomenon was periodic, or that while one month gave many spots another month might be entirely spotless. If sun spots were large they were far more likely to be noted than when they were small and numerous, especially when telescopes were poor and the mode of observing was to throw the sun's image on a screen in a dark room; but all such observations wanted precision and regularity. Yet, it must be allowed, that Dr. Wolf's arbitrary formula enabled him to give a fair approximation to the truth. This formula is $r = k(f + 10g)$ in which r is what the Dr. calls a relative number, f the total number of spots observed, g the number of groups, and k is equal to unity for a three-inch telescope with a power of 64 in the hands of a practical observer. But why the term $+ 10g$ enters into the formula is not explained, nor why the coefficient 10 is deemed necessary or whence derived.

Now, as we have elsewhere remarked, there is a great discrepancy between our theory and Dr. Wolf in the case of the maximum recorded by him for 1788. According to our table this was near the minimum. Of course it may be possible that there were a good many spots visible at that time; but it appears that many physicists are strongly of the opinion that a sun-spot maximum should be recognized in 1794, which would be altogether incompatible with a maximum in 1788; but it would give the average interval between the maxima and minima to regard 1788 as the epoch of the minimum. Leaving this for future investigation, we will pass on and compare the curve of the spot period with the curve of our theory, referring to our diagram (Fig. 24), and to Table III. These are at least founded on the inexorable logic of numbers,

while the spot curve represents observed facts, affected by the uncertainties of human judgment in assigning to each a just numerical value.

Beginning our comparison with 1798, instead of 1788, we see the minimum of the theory correspond with the recorded minimum. In 1811, again, the two minima coincide. The Wolfian curve makes the minimum in 1823, whereas our theory gives 1822. In 1834 there is very little difference between the two minima. In 1844 the two again coincide, within a few months, but in the following minimum we have the only real difference in the series. Wolf gives 1856, while our theory makes the minimum in 1854. The next minimum is 1867, at which date the two curves exactly correspond. Dr. Wolf's list of minima does not extend further, but from other sources the minimum has been fixed in 1878-9, whereas our theory gives it in 1877. (See reference, p. 87.) Now let us compare the epochs of maximum sun spots with our theory. We begin with the maximum of 1793, which, we have already shown, is at variance with the Wolfian epoch of 1788, but which seems, nevertheless, to have been a maximum according to the opinion of many astronomers. The next maximum occurs in 1804, which agrees with our figures exactly, as also does the following one in 1816. Then comes a difference of two years between 1828 and 1830, which last is set down in Wolf's series as the maximum epoch, although followed by another maximum in 1837, to which our theory also refuses to conform very closely; but a few pages back the reader will find these discrepancies explained. In 1848 there is also a difference of a year; but in 1860—the next maximum—the two curves are very nearly identical in time and features. A maximum is generally assigned to 1870, but from the way we have combined Wolf's numbers to get the true average on Jan. 1st of each year, the maximum was in 1871, and our theory gives 1872; while the next maximum is yet in abeyance. The Signal Office of the

United States gives 1882-4 as the present maximum, which, according to our curve, will be a little modified by future observations. In relation to the last maximum—1871—it may be said in favor of our own date—1872—that the years from 1870 to 1873, inclusive, were remarkable for spots and groups of enormous size, indicating great activity of the solar forces in 1872.

But it is not by an absolutely exact correspondence of two curves that such a theory should be tested; for, if it be true, its testimony is a far more reliable standard to refer to than Dr. Wolf's arbitrary numbers—being rigidly linked to the planetary movements by mathematical formulæ which cannot be controverted. The proper test is a general, rather than a particular, endorsement of the record; a similarity in the law of acceleration and retardation from minima to maxima and from maxima to minima; a similar average extent of the deviations in such changes, and, more especially, an average equality of the intervals between the maxima and minima. Such tests, we contend, our theory can stand without flinching; but we will bring additional proof of the legitimacy of its claims, in another chapter, after we have put our *electric vortices* to the test of fact.

It is now made apparent to the reader that we rely upon two principal mechanical processes to produce the solar spots, both dependent on the varying influences of every planet of the system according to its distance and position at any given date, and that both processes harmonize in time and force, reconciling the spot-period with the planetary motions. That they do harmonize in giving the zone of maximum spots where observation establishes it. That they do harmonize in accounting for minor periods of maxima and minima—the "small undulations" of Dr. Wolf. That they do harmonize in testifying that, while the moving power is outside the sun, the spots themselves proceed from within, and generally, that they do harmonize in explaining all the physical peculi-

arities of the phenomenon on mechanical principles. Furthermore, as the ethereal or electric fluid called to the solar surface by these two agents moves spirally upwards, one representing a general and the other a locally limited rarefaction, they nevertheless harmonize, and must harmonize in the direction of that spiral motion; for the induced current of restoration due to the revolution and rotation of the sun, must, like the sun, revolve from right to left in the northern hemisphere, and in the line of its motion.

Some have observed cyclonic motions in the spots from right to left, and others from left to right, in both hemispheres. Still this does not interfere with the effects of vorticose motion in the umbra of a great spot. Its centre will be more or less depressed by rotation, sufficiently to exclude the light of the photosphere, although its real elevation may be considerably higher than the photosphere. What the elevation of the outer crater-like ridge may be above the level of the photosphere is a more difficult question to answer, but from some few opportunities which the author has been favored with, he considers one second of arc close to the limb, seen over a wall of faculæ, as a fair estimate. This was in the case of a spot 30,000 miles in diameter, which would give a slope of 5° from the outer ridge at the top of the penumbra to the level of the photosphere.

Around the outer margin of the penumbra the author has often observed during the period of maturity that the photosphere is exceptionally bright, as if the vapors of the umbra (regarding the matter of the umbra and penumbra as identical and only differing in this, that the penumbra becomes visible by reflected light) acted as a stimulus to the fire raging around, and disappeared like dry grass before the lightning.

When the current which produces a spot begins to flag the vorticose motion in the centre ceases, and there is no longer that centrifugal tendency which depresses the

top of the umbra and renders it invisible. The consequence is that the outer ridge subsides. This lets in the light from the photosphere, the black centre disappears, and there is nothing but penumbra left, which presently breaks up and divides as the clouds do in our own atmosphere, and what remains is intersected by zigzag chasms and lanes, through which we see the photosphere until, by mingling with this last, the penumbra finally vanishes,

> "And, like the baseless fabric of a dream,
> Leaves not a trace behind."

The solar spots are not such formidable mysteries after all. They are evidences of the action of disturbing forces, which forces may, *and do* undoubtedly, disturb the planets; but the spots themselves are but the thunder-heads of the sun, and pass away with the exciting cause. According to this view there is no great mystery in the sudden change of figure and total disappearance of spots, as has been recorded by some, and even the spot seen by Wollaston to burst asunder, and the flying into pieces like a cake of ice dashed on a frozen pond, might involve but a small amount of motion in lines of elevation from below, by bringing portions of the umbra into the light, or even by an unequal sinking of the central parts of a spot and its absorption by the photosphere.

As the spiral or cyclonic feature of the spots is an observed phenomenon, and yet does not appear to follow one uniform law, we will examine the discrepancy and give a little more explanation, as it may be supposed that such motion may clash with other explanations we have given of the course of the axial or polar stream. As the whole vortex is in motion, this polar current must partake of that vortex motion and move spirally inwards. Now, although we have shown in our diagram (Fig. 21) the course of a particle of planetary matter under the influence of gravitation, yet it may be said that it does not follow that the ethereal current moves in the same

hyperbolic track. Human experience and practice have, from the beginning, been founded on the idea that a theory which reconciles effects to common or intelligible causes may for the time being be considered true. Science may demand proof; but there are many things confessed to be inexplicable, which for all that, are ordinarily received as axiomatic truths. Now, if a theory of the ether, such as we have discussed, throws a light on physical questions which we cannot derive from ignoring an implied *modus agendi*, or even its existence, we are justified in regarding it as *provisionally* true. Therefore we assume that the ethereal fluid *does* follow the same hyperbolic track as a particle of ponderable matter in descending to the sun, and is, in some way, *induced* to do so, while at the same time it is moving spirally from right to left in the sun's north polar current, and the reverse in the south. By following the curve in the diagram and assuming the possibility of the ethereal fluid passing through the sun, it will emerge south of the equator with the same spiral motion, which in its upward motion would be from left to right. If it emerged north of the equator this motion would be contrary to the normal motion of the vortex in that hemisphere. By following the curve down the southern pole with the same spiral motion it will be seen to emerge in the northern hemisphere as a right to left spiral. This permeation of the whole body of the sun by the ether is, of course, based on the hypothesis of that body being gaseous from centre to surface. But from observation it has been proved that, while spiral motions are frequent, they are frequently contrary in direction in the same hemisphere. This we regard as another confirmation of our theory which, by referring the spots to a current of restoration, shows that the moving power may be from above or below.

When a lateral vortex is in a given heliocentric longitude, that longitude is fixed for the time being, and is

only affected by the revolution of the sun and not by its rotation, as it is in the outside vortex and not in the sun. The solar surface, immediately below, is carried rapidly under it, and if, either at moderate or profound depths, the adjacent parts are in the necessary state of electric tension, that short period is sufficient, by the derangement of the equilibrium, to cause an electric current to ascend, carrying up with it (as we have before shown) a gaseous current which will necessarily partake more or less of the spiral motion of the lateral vortex which called it forth, which must necessarily be that of the great Central vortex.

When a spot is produced by the change of place caused by the sun's rotation (an effect only produced when the sun is not near the minimum), a similar current is produced under the same circumstances of local tension; but the escaping ether comes from the nearest opposite side of the sun, *on the same parallel*, where the spiral motion of the vortex, taken as perpendicular to the surface, is just contrary; so that when it emerges at the surface opposite to where it started, it comes in the northern hemisphere with a motion from left to right, and in the southern hemisphere with a right to left motion. We have emphasized "*on the same parallel*" for the reason that, a point diametrically opposite to any particular latitude must be in the opposite hemisphere, and such point would not be any nearer to the axis nor have any greater distance, than a point in the same latitude and hemisphere, while the line through the sun would be increased, and it is a feature of the electric or ethereal fluid always to choose the shortest route.

CHAPTER VIII.

THE LIGHT AND HEAT OF THE SUN.

If there be any one question in solar physics which fastens itself more tenaciously on the minds of even ordinary thinkers than any other, it is this: whence does the sun receive its fuel to maintain its prodigal expenditure of light and heat?

Geology goes so far back into the past in fixing the embryotic state of the earth, and reveals so many evidences of solar influence in the Flora of our coal beds, that the existence of the sun in those early periods may be assumed as certain. How much further

"In the dark backward and abysm of time"

the sun assumed its present proportions, it is not for man to know. It may have been millions of years, without vitiating one line of Holy Writ; for the Great God, whose will is the fountain of all being, appears as lavish of time as of space in all the arrangements of the universe which man can investigate. Infinity and eternity are His great attributes, and Revelation only refers to the things and times coeval with the existence of the beings to whom the Revelation is made.

Giving then to the sun an indefinite past, the conviction is forced upon us that, if the light and heat which it so liberally dispenses, were not rendered back in some form or other, the light would have faded and the heat would have diminished so rapidly, that by this time, it would have become a solid mass of dark matter, but very little hotter than the surrounding space, if its original temperature had been no greater than at present.

It has been calculated by Sir John Herschel, that the

heat of the sun directed perpendicularly upon our globe would melt a sheet of ice one inch thick in 2*h.* 13*m.*, which would give a thickness of 165 feet in a year for the whole earth,* which, reduced to tons, would give 130,000,000,000,000, or one hundred and thirty millions of millions of tons of ice which the sun would melt in a single year; yet this is not the two thousand millionth part of the solar radiation. In fact all the planets in the solar system can only intercept, unitedly, about ten times as much as the earth, so that, it may be said that all the heat and light of the sun is wasted (so far as the occupants of the various planets are concerned) except the $\frac{1}{2000000000}$th part of the whole. Yet the sun has shown no signs of decay through the long years during which man has existed upon the earth, and herein lies the great mystery of mysteries.

Two theories are held by men of science to escape the conclusions drawn from the above. One is based on the known fact that meteors do sometimes (but very rarely) fall upon the earth from the outer space, and if upon the earth, why not upon the sun? From Professor Newton's investigations it may be admitted that millions of meteors annually pass through the upper layers of the earth's atmosphere, but it is far more probable that they are rendered visible by friction, and merely glance *upon* the atmosphere than that they are consumed *in* the atmosphere. In Great Britain only four well authenticated cases of the fall of solid meteors have been recorded, and they are equally rare in other parts of the world. It is, therefore, contrary to all experience to suppose that the solar light and heat are kept up by an incessant meteoric rain, however possible it may be to show the adequacy of the cause. Another theory is that of Helmholtz, who refers the origin of the continual supply to a contraction of the solar diameter by about 250 feet in a year. Subsequently it has been shown that a gaseous body can con-

* Pouillet gets 100 feet by a different process.

tract by cooling and yet become no cooler, but rather hotter. This does truly appear paradoxical. Gases owe their volume to two causes: pressure and temperature. If by loss of temperature the volume contracts, then (it is said) its temperature rises above what it originally was. But say it gains just as much by the contraction as it loses. The temperature, therefore, is just what it was at first, and the volume is precisely the same volume due to that temperature. We cannot argue that by contraction the layers are brought nearer the centre of attraction, and therefore the contraction is increased, because a contrary effect would be produced. Outside a sphere at two given distances the central attraction would be the greatest at the least distance, and within a sphere the nearer the centre the less would be the attraction; but in this case every layer is getting nearer the centre, or in other words, the radius of the whole sphere is diminishing while the mass remains the same. This increases the attraction, which in time increases the temperature, and so diminishes the contraction. These antithetical operations have never been formulated *in extenso*. Neither Helmholtz nor Mayer have shown their conclusions to be based on experiments sufficiently fortified. The law of cooling may vary materially with change of volume while the mass remains the same, and no branch of physics is so replete with unexpected departures from the inferences of experience as that of heat and light. The mere mathematician is not a fit arbiter in such a case.

This is a problem which depends altogether on the data and scarcely warrants the confidence exhibited in its partial solution; for the question will ever present itself in this form: How can the sun lose heat by contraction when that contraction must give out more heat (to supply the loss by radiation and still keep up the original temperature) *at the same instant of time?* for if the temperature increases (or even remains the same) there can be no contraction, and if no contraction no development of heat.

But the differential calculus is a wonderful instrument in the hands of a *skilful* mathematician, and they who are not analysts, while submitting to its authority, have at least Galileo's privilege of murmuring, *sotto voce*, "*Pero se muove.*"

Another theory has lately attracted some attention, which is of a totally different character to the meteoric theory of Sir Wm. Thomson, and the contraction theory of Helmholtz. This is from Dr. Siemens, of London, a well-known physicist, who lays down the following fundamental conditions (see "Observatory" of May, 1882):

"1st. That aqueous vapor and carbon compounds are present in stellar and interplanetary space.

"2d. That these gaseous compounds are capable of being dissociated by radiant solar energy while in a state of extreme attenuation.

"3d. That these dissociated vapors are capable of being compressed into the solar atmosphere by a process of interchange with an equal amount of reassociated vapors, the interchange being effected by the centrifugal action of the sun itself."

When learned men resort to such uncertain and overtaxed methods to accomplish the same objects which could be attained by admitting our fundamental postulates, in a far higher degree, and when others equally learned allow themselves to ridicule a theory against which no charge can be brought of outraging mathematical or mechanical principles, we may well despair of the future, and deplore the blindness which cannot be remedied.

What becomes of the boasted precision of astronomical computation if interplanetary space be occupied by aqueous vapor and carbon compounds of a density as great as $\frac{1}{2000}$th of our surface atmosphere? If these vapors are capable of being decomposed by radiant solar energy in the interplanetary spaces, why does not the same radiant energy affect the same dissociation on the

earth, where water and aqueous vapor are so abundant? If this were so, our atmosphere would soon become tainted with hydrogen, and a little later would reach the explosive point and a second universal deluge would wipe every living thing off the face of the earth, either by fire, or water, or suffocation. These dissociated elements, according to Dr. Siemens, constitute the fuel which restores the wasted energy of the sun, or that part which is not utilized by the planets. Even that portion cannot be said to be wasted, as it is employed in dissociating the same elements over and over again, after being forced back to the sun by a process of circulation produced by his rotation. This process consists in throwing off the ashes of the combustion from the equator, which crowds the *dissociated* elements to the poles, by which process they, finally, reach the surface to be again combined by combustion. And so the sun prepares his own fuel, and there is no loss of radiant energy, provided there be at least 5 per cent. of pure hydrogen or carburetted hydrogen in a current of other gases, rushing upon the sun with a velocity of a hundred feet per second!!!

It is evident, in this theory, that the Newtonian law of gravitation is ignored. The aqueous vapor and carbon compounds, unfortunately, are molecules or atoms of ponderable matter, and a single atom is as much amenable to the gravitating force as the planet Jupiter. Each atom has its orbit, its nodes, its perihelion and aphelion, and these orbits are not disturbed except by an adequate force; how then do they get to the polar regions of the sun when they are projected from the equator, and why don't they fall upon the equator as well as near the poles? But a still stronger objection remains. The gravitation of the sun is 28 times that of the earth, and the centrifugal force of its equator only $\frac{1}{8}$th that of the earth; how then can any ponderable matter be projected from the solar equator by centrifugal force?

It surely cannot be considered *mal à propos* to remind

the reader that the *idea* of an incessant inrush of planetary particles into the solar vortex at the poles, and thence being deflected outwards along its equatorial plane by the great radial stream of the solar vortex, and the gravitating force conjointly, was published by the author, in 1854, in his "Mechanical Theory of Storms." This is now one of the principal features of the present more advanced state of his theory; but it is a feature not exposed to the grave objection which can be urged against Dr. Siemens' "fundamental conditions," which require the inter-planetary spaces to be filled with an atmosphere of ponderable molecules and atoms, constituting a medium whose density may be $\frac{1}{20000}$th of the air we breathe; for if such density existed in those spaces, the planetary atmospheres would be denser than water. Even if that density were only $\frac{1}{2000000}$th of atmospheric air, such a resisting medium would subvert the whole fabric of modern astronomy.

But the sun shows no signs of failing powers, neither is it likely that it ever will, so far as its dependence on the fuel supply is concerned. It no doubt had a beginning, for it was created, and so was man; but there are few living, whether believers or unbelievers, who like to admit that because they had a beginning they will surely have an end. Yet the testimony of the Scriptures is decidedly more explicit that the sun shall endure forever, than that immortality is to be the lot of all. For of the KING it is written, "His name shall endure forever: his name shall be continued as long as the sun." (Psalm LXXII. v. 17.) And that by the sun is meant our material sun, is proved by another passage referring to the same glorious name in Psalm LXXXIX. v. 36–37, where speaking of David's seed, which it is said:

"Shall endure forever and his throne as the sun before me. It shall be established forever as the *moon*." But where can we find any such passages promising immortality to the scoffer?

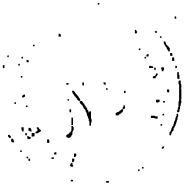
Now let us face this great question of the visible creation with a sincere desire to do it justice, regardless of the endeavors of vain philosophy to enshroud it with metaphysical speculations; and give heed to those plain and simple arguments which are least likely to lead us astray. If, as we cannot deny, space be infinite, we must also admit it to be replete with some form of matter which is imponderable. If the temperature of bodies be a measure of their atomic motion (a postulate no one can deny), this motion must be imparted to the medium of space and conveyed to us as light and heat by its vibrations. As we see stars at inconceivable distances they tell us that medium extends at least to them; but whatever difficulties and peculiarities may attach to *electric phenomena*, we can hardly escape the conviction that there is such a thing as an *electric fluid*, analogous to just such an imponderable medium as we have reason to suppose the medium of space to be. But this electric medium is elastic, and therefore compressible, and so must also be the medium of space: for extreme mobility (one of its characteristics) exacts this admission as a condition precedent to that mobility. The motion of the electric *fluid* produces mechanical effects, very frequently exhibited, and no good reason can be assigned why the one is not identical with the other, if we are willing to leave a few questions in abeyance until our ignorance or prejudices are dispelled by an increase of faith in the conviction that all natural problems will ultimately be reconciled to reason and dynamics.

Let us exercise that faith in the case before us, and admit the postulate: That infinite space is a reservoir of imponderable matter which, from all the analogies of nature, is never at rest, but flows onward in streams of unutterable vastness, and with inconceivable velocities, throughout infinity and eternity, and we shall find in this admission an easy answer to the question: From whence does the sun derive his supplies of light and heat, and

why are they distributed with such apparent indifference to their utilization?

It is only of late years that even scientific men have begun to pay much attention to the inquiry into the nature and characteristics of this universal medium; but now the motion of the *Ether* is a subject which engages the attention of the most noted astronomers. How it could ever be doubted that the ether was in motion is one of the most inexplicable vagaries of the human mind, and yet there are such men to this day who think it savors of wisdom to ignore its existence altogether.

We have already made it plain to the reader how, in a material fluid possessing inertia without ponderosity, the rotation around an axis rarefies the interior of a vortex, which rarefaction begets a polar or axial indraught to restore the equilibrium (an explanation far more intelligible and compatible with dynamical principles than Dr. Siemens' gigantic fan-wheel winnowing the chaff from the solar elements), which inward current we call the polar stream, as we call the outward current from the axis the equatorial or radial stream. If, as it must be to be in accordance with mechanical principles, the centre of gravity of the ponderable bodies in the solar system occupies the mechanical (and also the geometrical) centre of the ethereal vortex, which, for the moment, we will consider identical with the centre of the sun, this polar current coming in opposite directions strikes the polar regions, penetrates no doubt far into the solar orb, and inclines to the side of least resistance, which is to be estimated by the density of the ether and not by that of ponderable matter. A ray of light inclines to the central parts of a lens; for there the ether is less dense, so an ethereal stream would diverge to the side of the sun if the sun were at the centre, and, therefore, follow the same curve as a particle moving in a conic section under the law of gravitation. We reproduce our figure here, exhibiting the curve of such a stream in one vertical plane, but, in



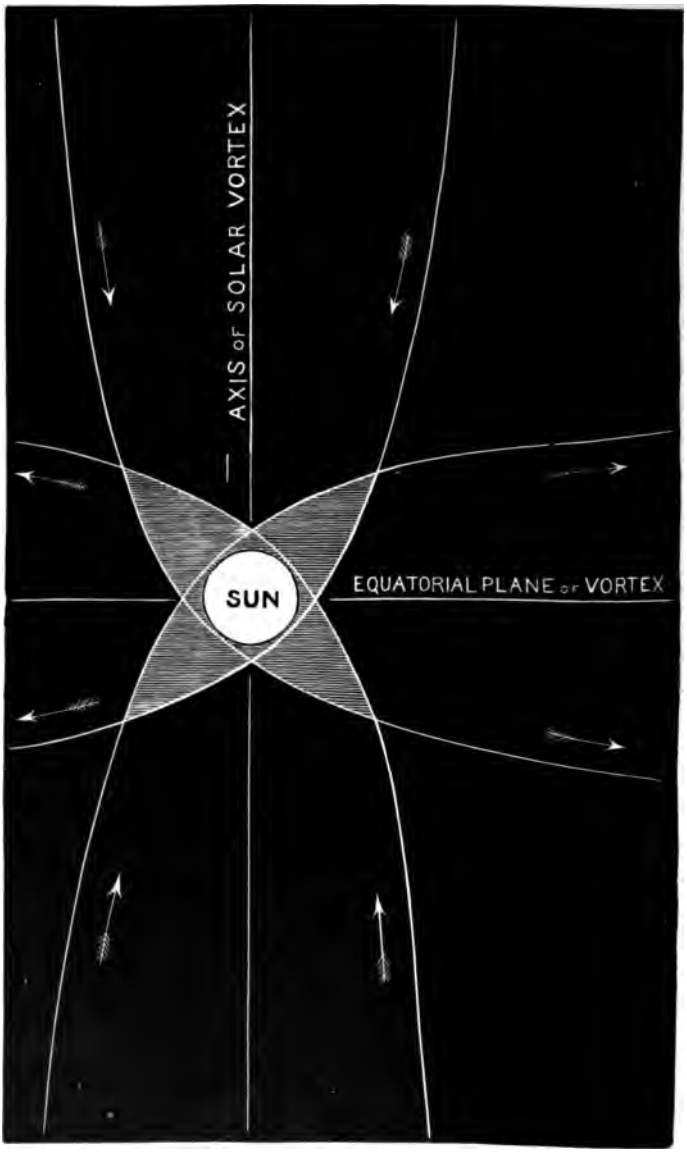


FIG. 25. - SHOWING THE PROBABLE ORIGIN OF THE QUADRANGULAR OUTLINE OF THE SOLAR CORONA.

But in the solar system the sun may safely be said never to occupy, even approximately, the centre of the system; so that there is not that symmetry of parts which we have just supposed. Nevertheless the current flows onward; but there is more of a *chaotic* derangement on the surface of the sun when the displacement is a maximum, and less symmetry in the corona during eclipses at such times.

It would not perhaps be superfluous to admonish the reader against a possible misconception of our meaning in speaking of the great inrushing currents of ether at the centre of the system, being due to the rarefaction around the centre by the centrifugal force of rotation. This is truly the exciting cause; but, as we have explained, in our exposition of the solar spots, the polar stream comes down to the centre with the normal density of the outer space. It is there met by a counter current from the opposite pole. These two currents, mutually permeating and interpenetrating each other, are really condensed by collision with the sun, and by their own mutual actions: so that the centre of the vortex is really the place of greatest density, constantly relieved, however, by the tremendous velocity with which the ether expands into the rarefied space outside this inner sanctuary of condensation. The sun, like all refracting bodies, is, however, permeated by ether of a less degree of density.

If, then, we have a right conception of the course pursued by the incoming stream of the solar vortex, we can, at least, imagine this general consequence: There will be a confusion of opposing streams around the sun when in his normal position of *the* great central body, from which all the heat wasted in the system may be obtained even if we leave out the friction caused by the obstructing matter of the sun itself; but really the sun is the carbon point of the quasi omnipotent electrodes, and thus becomes the centre from which light and heat are dispensed to the planets around it.

The effects of this great stream of ether (called radial from its approximate direction to a radial line drawn to the axis of the vortex) cannot be overestimated. It is that which thrills through the whole system with a velocity almost equal to that of light, and making itself *felt* throughout the whole field of meteorology, in storms and cyclones, in earthquakes and volcanoes, in magnetism and the aurora; to say nothing of its mysterious influence on human health and comfort. Let us conceive a thousand nozzles of a thousand steam pipes all directed to a single point, from the surface of a spherical space just large enough to permit such crowding, and all emitting steam of the highest known pressure, we may then get a faint idea of the incomprehensible turmoil of material impacts which grind out the fuel supply of the solar system. As we have before stated, this gives the preponderance to the equatorial parts which are found to be the hottest (we divide polar from equatorial by the 45th parallel). The difference between the two portions would be simply immeasurable if the sun were solid. As it is only small, we take it as a proof that the whole body of the sun is gaseous to the core.

Now, in addition to this, we must insist on another important postulate of our theory, as auxiliary to what has been already advanced. The specific heat of the ethereal medium must be approximately in its general condition, inversely as its density, and, therefore, exceeding, volume for volume, that of all known material substances. This is a very potent factor in the question before us.

If the sun were always in the centre of the system, the temperature of our globe would no doubt be more equable and higher than it usually is. If the sun's displacement were always at a maximum, storms and great electrical excitement with sudden extremes of heat and cold (the last in greater excess) would characterize the seasons.

But besides the effects of this overwhelming indraught from the outer space, which *mainly* supplies the sun with

his heat and light, there is another source which is less variable in its influence. This is caused by the rotation of the sun itself. When, as we have already explained, any portion of the sun, which in 12.75 days is carried to the greatest distance from the axis charged with the dense ether of the inner space, there parts with the excess, and in another 12.75 days is again recharged, it is thus subject to a continual internal friction from the ebb and flow of this ethereal tide, which acts as a heat generator, and is perpetual. If it be objected that the known low temperature of the inflowing ether must have a contrary effect, we have but to remind the reader of the tremendous character of this influx at the centre. It may be conceived that so much heat is generated there by the condensation and conflict of opposing currents, as would make the sun immensely hotter if it were always in the centre of the vortex, where it would be exposed *all the time* to the temperature of that inner space and to the friction of the central polar currents. If our theory of an ultra Neptunian planet may be modified, by showing that the same effects can be produced by two or three outside planets, a time may arrive when the positions of all the planets will, for some considerable time, place the centre of the sun in the centre of the vortex, and render the solar radiation seven-fold as is explicitly foretold. Be this as it may, we have in the rotation as well as in the revolution of the sun a source of heat auxiliary to the effects produced by the polar stream of the vortex, all which we may safely regard as an ample supply to keep up the present temperature of the sun for all eternity.

And here we may allude to the tardiness with which man receives from nature those practically useful hints which he ultimately begins to appreciate. Now we are beginning to realize that the sun's light is electric, produced by a current rendering ponderable matter incandescent, and we imitate the process by illuminating with the electric light the scenes which the sun has left in darkness.

If we are somewhat despondent from our experience of the treatment this theory of electric vortices has received during the last thirty years, it is because of a growing conviction that the scientific world, as a body, loves darkness rather than light. Here is a theory the fruits of forty years of observation and persevering labor; the truth of which is so palpable, not only as to the existence of these vortices in our atmosphere, but of the accuracy of the elements by which their visible passages can be calculated, which elements have been tendered to the world, but no one will examine whether these things be so or not, and when the same theory, which would go far to disarm the storm upon the earth, is extended to the whole visible creation of God, the response is unanimous; for every physical phenomenon is tuned to the same key-note, and rings out a universal *Aye*. But science proudly negatives the verdict, and pronounces as nonsense a palpable fact which forces itself upon the attention of every human being, nearly, as frequently as the rising and setting of the sun.

Surely the spirit of Nemesis has revisited the earth to wring from science the following truthful dirge:

"One is almost ready to despair of the cause of scientific progress—to despair at least that that progress will ever be so rapid as it might readily become—when one finds that each new result must be established over and over again before it is admitted by a large proportion of the scientific world. It may be remarked, indeed, that the progress of science has been at least as seriously checked by undue caution as by undue boldness. It would seem almost as though some students of science were continually in dread lest the work of our observers should become too productive. The value of scientific observation seems to be enhanced in their eyes precisely in proportion as its fruits are insignificant. In all ages there have been those who would thus unwisely restrain the progress of legitimate inquiry. 'We must not admit

that Jupiter has moons,' they said of old, 'the Evil One may have sent these appearances to deceive us. Let us wait for further observation.' 'The sun cannot have spots,' they reasoned again, 'for the Eye of the Universe cannot suffer from ophthalmia. These things are illusions: let us wait for more satisfactory observations.' 'The idea that the sun spots wax and wane in a definite period is too fanciful for acceptance; and still more absurd is the conception that terrestrial magnetism can have any relations whatever with the progress of solar disturbance. We must wait for fresh researches.' 'Who can believe that flames or clouds or mountains, many times exceeding the Earth in magnitude, exist upon or close by the Sun? These things must needs be illusions; at any rate, fresh observations are required before such marvels can be admitted.' And as this *has* happened with facts now accepted, so it *is* happening, and so (it is feared) it will always happen, *as respects many other facts, which have been in truth demonstrated*, but the demonstration of which does not chance to lie exactly on the surface." (The italics are ours.)

(See Proctor's Sun, p. 260.)

Science tells us that the sun must come to an end. How much more cheering is the thought that whatever *changes* the earth may undergo there is abundant evidence that no such ignominious sequel is reserved for the sun and his family of planets, as computed by a great authority, who asserts that, ten millions of years hence, the sun's heat will have so diminished that the earth will no longer be able to sustain life, and that in five millions of years the temperature must have begun to fall. But with even this long lease before us, it would be melancholy to contemplate such a finale, if it were anything more than a scientific delusion. "He who laid the foundations of the earth that it should not be removed forever" must feel greatly honored to have His work guaranteed for so long a period as five millions of years. But it would be a

gloomy prospect for faith to ponder over; to think that our glorious inheritance must ultimately become a frozen wilderness circulating around a sun blasted with an eternity of darkness, unless some friendly star should be willing to revivify it by a collision, which would probably blot out all life existing in its dependant planets. But wisdom is truly justified of her children, as the above is characteristic of the scientific induction now in fashion. A theory independent enough to question the conclusions of the inner circle, is denounced as "nonsense"—a mere speculation, justified by no "*a priori* probability of being true." In its place, we have the theory of contraction treated as if its data were unquestionable facts. But we must take the liberty of proclaiming that there is not the slightest warrant for assuming that the sun is contracting, and deny that any process of cooling whose rate is obtained by any of those means within the reach of science, is competent to give sufficient contraction to maintain the sun at its present temperature, or even supply a small fraction of the annual drain.

There are, however, some minds candid enough to acknowledge the necessity of taking the motions of the ethereal medium into account. At a recent meeting of the Royal Astronomical Society of London, the question of the motion of the ethereal medium came up in connection with the aberration of light, and the difference between the experimental and the astronomical determination of its velocity. In 1854 the author endeavored to draw attention to this necessity in the following words:

"But will not the admission of a vorticose motion in the ethereal medium affect the aberration of light? It is well known that the question has been mooted, whether the velocity of reflected light is the same as that of direct light. The value of aberration having been considered 20″25 from the eclipses of Jupiter's satellites, while later determinations from observations on Polaris give 20″.45. It cannot be doubted that light, in traversing the central

parts of the solar vortex, that is, having to cross the whole orbit of the earth, should pass this distance in a portion of time somewhat different to a similar distance outside the earth's orbit, where the density is greater, and, consequently, induce an error in the aberration determined by the eclipses of Jupiter's satellites." (See "Mechanical Theory of Storms," p. 181.)

In addition to which it may be said that a slight difference between the circular motion of the ether and the revolution of the planets, may *bring a ray of light on its arrival at the earth into the same direct line joining the centres by which it started from the sun eight minutes before*, and, therefore, the objection that any interference of opposing waves, producing a tangential disturbing force is altogether dependent on that motion, and gravitation (or some other force varying inversely as the squares of the distances) may be produced by the interchange of light and heat waves, between planetary bodies, and by their consequent interference. But this question is one foreign to our present purpose and in no way affects our general theory. All we know is this—gravitation is a reality following the Newtonian law, and may originate in the existence of a fluid whose tenuity may exceed that of the ethereal medium, as much as that last exceeds our heaviest gases in that particular feature.

But questions will arise in the near future as to the effect which the motions of the ether have, not only on the undulatory theory of light, but on the law of gravitation, as affected by the ever-rushing stream of ether outwards from the sun; the admission of which is the *sine qua non* to further progress.*

* In the appendix, Note I, will be found references to certain facts and conclusions gleaned from published views and discoveries, which have recently come to light and confirm the present theory.

CHAPTER IX.

COMETARY PHENOMENA.

In the appendix to this volume will be found an extract on the subject of comets, from our "Mechanical Theory of Storms," published in 1854 (Note H), which places the question in a fuller light than we can hope the general reader would here appreciate; but the application of our theory of electric vortices to the most important and striking phenomena of physics, would be incomplete if we omitted to show how unmistakably the comet bears witness to the same celestial mechanism as the spots and corona of the sun, especially to that most important consequence of all: *The perpetual rush of an ethereal current from the sun, the non-admission of which will forever involve science in difficulties and inconsistencies.* In other words, it is an electric gale ever blowing outward. It is the force which strips the comet of its outer garment, and sends it forth as that luminous appendage called its tail. No repulsive power of the solar rays can satisfy the conditions, neither is there any occult power of repulsion in nature to meet the emergencies of the case. But we will bring some of these sidereal messengers into court and listen to their testimony.

At present there are but a few comets whose return may be *confidently* looked for. Of these, Encke's, in its little orbit of 3¼ years' period, and Faye's about double the period, with Halley's *retrograde* comet, whose aphelion distance is about 500 millions of miles outside of Neptune's orbit (an argument for our Planet VIII.) may be considered life-members of the system. The standing of others, such as De Vico's, Brorsen's, D'Arrest's, Tuttle's,

Winnecke's, Temple's, and some recent ones, rest on no surer foundation than Biela's, which seems to have retired from business in 1852, after a fair division of its assets among its creditors, while many others have failed to keep their appointments; and no comet of long period, except Halley's, has verified its pre-calculated return.

Ordinarily, a comet of long period comes unexpectedly, remains for a few weeks or months within the range of visibility, and then disappears, never again to be observed by the then existing generation of mankind. From numerous concurrent testimonies, the evidence is against comets possessing sufficient mass to disturb the planetary motions, and even where solid nuclei are with great reason credited to some of these bodies, these nuclei are usually very small, although representing pretty nearly all of a comet's mass. The general evidence is decidedly in favor of a comet being a gaseous body throughout; but in discussing their peculiarities, this feature cannot be safely regarded as without exception. The central attraction may, however, be roughly ascertained by the measured diameter of the nucleus, assumed to be composed of our familiar gases. The earth, with its ponderous mass, is only able to create a barometric pressure of fifteen pounds to the square inch of surface in a depth of 50 miles, and the volume is inversely as the pressure. If the earth's mass were reduced to one half, the atmosphere would extend 100 miles above the surface, and if comets were spherical collections of atmospheric air, there seems no reason why this law should not be applicable to them. Leaving out the decrease in the gravitating force due to elevation, a comet of 50,000 miles in semi-diameter, might be said to have a mass sufficient to limit that semi-diameter to 50,000 miles, or it would be greater. But this would imply a mass equal to $\frac{1}{1000}$th part of the earth's mass, or $\frac{1}{12}$th part of the moon's mass. If the semi-diameter were less than 50,000 miles, then the mass ought to be greater.

A few years ago (and with many the same idea yet pre-

vails) a comet was regarded as so insignificant that the question of a collision with the earth was compared to that of a fly against an express train at its highest speed. Babinet, a French savant, designates it as a visible nothing (*rien visible*). Even Sir John Herschel held to the opinion that a comet's mass only weighed a few ounces. But these are wild and extravagant opinions when we know that such comets as those of A.D. 1006, 1402, 1532, 1577, 1618, 1744, and 1843, were all visible in bright sunshine, and some of them close to the body of the noon-day sun. No wonder there are scientists and astronomers who can, from other data, get totally different results to those of the Babinet school.

This idea of obtaining an approximate estimate of a comet's mass by the diameter of its nucleus (leaving its nebulosity out of the question) was advanced by the author in 1854 in a chapter on comets in the volume to which reference has been made above. A few of the positions then held have been modified; but far more have been confirmed and expanded by recent observations. The reader is therefore referred to the APPENDIX for a more full discussion of the subject. Here we shall only select a few known facts by which it can be tested, which facts will not only receive a satisfactory explanation, but which will, in turn, add greatly to its strength.

The approximate determination of a comet's mass from the diameter of its nucleus, has more recently been expanded by M. Roche, a French mathematician, by connecting the masses, diameters and distances, in his formula. Encke's comet he makes quite large, equal to $\frac{1}{1000}$th part of the mass of the earth, which is very probable, as this comet seems to have been so far sifted by the radial stream as to be reduced to tolerably dense elements. It has never been seen with a tail and, consequently, loses none of its mass at its perihelion passage, as is the case with other comets. Donati's comet he makes about the 20,000th part of the earth, or equal to a globe of water of

500 miles in diameter. In this way the masses and even densities of many comets have been computed, showing that while the views of M. Babinet are altogether imaginative, yet, as compared with the planets, comets have very little mass. In these calculations, however, that outer envelope of light surrounding a comet's nucleus, usually called its coma, is only credited with a small fraction of the mass of the nucleus, yet in some comets, as in that of 1811, while the nucleus was only the $\frac{1}{100}$th part of the volume of the earth, that of the coma was more than double the volume of the sun. Below we give a list of thirteen remarkable comets which have been measured. They are placed in the order of actual magnitudes:

NO. COMETS.		NUCLEI IN MILES.	NO. COMETS.		COMA IN MILES.
I.	1798	28	I.	1769	1,200
	1805	30		1807	1,900
I.	1799	385	V.	1847	17,900
I.	1811	429	I.	1847	25,400
	1807	550	II.	1849	50,700
II.	1811	2,700	I.	1843	94,500
I.	1819	3,300	Brorsen	1846	129,000
I.	1847	3,500	Lexell	1770	203,000
I.	1780	4,200	I.	1846	241,000
I.	1843	5,000	Encke	1828	264,000
	1815	5,300	I.	1780	267,000
VI.	1858	5,600	Halley	1835	354,000
	1769	28,000	I.	1811	1,120,000

From which it appears that the diameter of the coma of 1811 was 2600 times greater then that of the nucleus, and the volume was between sixty and seventy million times greater. This alone ought to determine the electric nature of the nebulosity and its insignificant agency in increasing the mass of the comet.

But that enormous volume also admonishes us that there must have been in that small nucleus a greater force than in many comets whose nuclei are larger.

It is true there are small diaphanous comets which imply an absence of all solidity in their nuclei. Again,

there are comets which, at their perihelion, vie in brightness with the sun itself.

Now we have to explain these anomalies by our theory. We have also to explain why a comet's diameter diminishes with its distance from the sun, and increases with its increase. We have to show why comets whose perihelion distance is small, project tails of such enormous dimensions *after* perihelion, especially if the perihelion distance is excessively small; and we have to show the reason for those tails, as well as for the jets emanating from that side of the comet nearest the sun, as the tails do from the side most distant from the sun, both when the comet is diminishing and increasing its distance. The rationale of other peculiarities can be readily inferred from the theory when these are elucidated.

From the great eccentricity of a comet's orbit its motion may be said to be almost directly to, or from the sun; its electric equilibrium, therefore, is constantly changing. Take now a comet approaching its perihelion. It comes permeated with the dense ether of the outside space which causes an escape of the ethereal medium, or in other words, it is positively electrified. It is, at the same time, coming more and more under the influence of the heating power of the sun, which still further increases its electric energy. Both these causes would operate according to a rational induction in expanding the volume of the comet, whereas *the contrary effect is produced*, as in so many natural phenomena, wherein human wisdom is so often baffled. The comet's volume contracts on approaching the sun, while the tail increases. But this general law is often transgressed in both cases, in the same comet at different distances, and in different comets at the same distances, from the sun.

In 1828 the diameters of Encke's comet were carefully measured and compared with the distances as they appear below. In addition, we have reduced those diameters to the same unit as the force represented by the 2.5th power

of the distance, which we deduce, as the true force of the radial stream, to which the elongation of the tail and the contraction of the diameter, are due. As the force of the radial stream (the electric wind) is inversely as the 2.5th power of the distances, and the diameters, as we contend, inversely as the forces, these diameters are, therefore, *directly* as the 2.5th power of the distances respectively.

ENCKE'S COMET, 1828.	DISTANCES IN UNITS OF EARTH'S DISTANCE.	2.5TH POWER OF DISTANCES.	DIAMETERS IN EARTH'S RADII.	DIAMETERS REDUCED TO COMMON UNIT.
October 28	1.4617	2.58	79.4	2.58
November 7	1.3217	2.01	64.8	2.10
" 30	0.9668	0.92	29.8	0.97
December 7	0.8473	0.67	19.9	0.65
" 14	0.7285	0.45	11.3	0.37
" 24	0.5419	0.21	3.1	0.10
		Sum 6.84		Sum 6.77
		6.77		
		6) .07 = 0.01 = Diff. of means.		

Taking the difference between the observed and calculated values of the diameters, we see from the above Table that it only amounts to 0.01. The principal difference is at the last dates when the comet was getting close to the plane of the vortex where the radial stream is the strongest, and, therefore, where the diameter diminishes in a more rapid ratio.

DONATI'S COMET, 1858.	DIAMETER OF NUCLEUS IN MILES.	LENGTH OF TAIL IN MILES.	DISTANCE FROM SUN IN MILES.
July 19	5,600		134,000,000
August 29		14,000,000	86,000,000
" 30	4,060		
September 8		16,000,000	71,000,000
" 13		20,500,000	
" 23		14,900,000	
" 28		26,000,000	55,000,000
" 30	Perihelion.		53,000,000
October 3		38,000,000	
" 5	400	41,000,000	56,000,000
" 8	1,100		
" 10	630	55,000,000	59,000,000
" 13		39,000,000	61,000,000

This is, perhaps, a fair sample of the way comets respect their distance from the sun. The nucleus of Encke's comet expands and contracts in a far greater ratio, as appears in the Table below:

ENCKE'S COMET, 1838.	DISTANCE IN MILES.	DIAM. OF NUCLEUS IN MILES.
October 9	132,000,000	278,000
" 25	111,000,000	119,000
November 6	93,000,000	80,000
" 13	82,000,000	75,000
" 16	77,000,000	62,000
" 20	70,000,000	55,000
" 23	66,000,000	37,000
" 24	64,000,000	30,000
December 12	36,000,000	6,500
" 14	33,000,000	5,500
" 16	32,000,000	4,200
" 17	31,000,000	3,000 Perihelion.

But Encke's may be considered as a comet of a totally different class to other comets, or, perhaps, unique in the density of its component gases, which gives it power to maintain itself so close to the sun; for all the planets are, probably without exception, of greater average density the nearer they are to the sun.

Now while we see that the law is not invariable, yet generally (and perhaps more generally than is admitted as there are so many ways in which errors of observation may be committed) a comet's diameter is greater the greater the distance, and a comet's tail is greater the less the distance. This last must, however, be conditioned on the perihelion distance. Those comets which almost graze the sun at perihelion (as, for instance, the comets of 1843 and 1680) only developed their enormous tails some considerable time after perihelion. It is incredible that the comet of 1843, which was not seen until discovered close to the body of the sun on the very day of its perihelion passage, should have escaped detection, if it had a tithe of its subsequent appendage. The comet passed its perihelion on the 27th of February, on the 28th

it was seen from a ship off the Cape of Good Hope. Its distance from the sun at this time was less than 4°. The tail and nucleus were equally bright, and allowing a little for the effect of perspective, the tail could not have exceeded 2,000,000 miles in length—its angular measure being only 1°. Now, let us remember that it swept around the sun in about two hours, going through 180° of its orbit, or half around the heavens, in that time, and that in twenty days from its perihelion it emitted a very brilliant rectilinear tail of about 200 millions of miles in length, having shot it out at the rate of 10 millions of miles a day. If the tail was longest at perihelion, then its extremity had swept around the heavens with that radius in two hours keeping itself on or near the lines of its radius vector all that time. *Credat Judæus.* It would be the greatest wonder in astronomy.

But we will be brief. A comet first becomes visible as a round or slightly elliptical nebulous body, with perhaps a star-like nucleus. It is mainly (we will suppose) a mass of gas, with a more substantial core or nucleus, perhaps solid, but very small. It comes from those regions of space where the ether is dense, and therefore is itself permeated by the same ether. As it shortens its distance from the sun the density of the ether diminishes very fast, as, in almost every case of very eccentric orbits, the comet's course is within 15° of a straight course to the sun. The comet soon begins to feel this diminution of pressure, and its attenuated outside layers are carried upward, principally in the hemisphere toward the sun, whose heating power also is most potent on the same side. As the distance diminishes very fast, this upward movement increases, until it is powerful enough to form those jets of apparent flame observable in all full-fledged comets, and in proportion to the energy of this action, is the light which it produces (a process similar to the production of the solar light on a small scale), a very small part of which is due to reflection.

But while thus hurrying towards the sun the comet is met by the radial stream of the vortex, whose force is (as we have shown) an expulsive force, whose ratio of increase is even greater than the law of gravitation, being inversely as the 2.5th power of the distances. The jets of light from the sunny side of the comet's nucleus are now turned fiercely backward in a sheet of nebulosity superficially conoidal in form, which envelops the nucleus and is carried to the side opposite to the sun to form the tail. As seen at a distance, the outer lines of such a hollow structure will be far brighter than the middle portions, on account of presenting more particles of cometary matter to the visual ray, and, therefore, the appearance will be that of a comet with two tails, and the intervening space only *dusted* with faint nebulosity. The great comet of 1811 had a series of such envelopes, widely separated, which no doubt indicated different ratios between the densities of the layers, and the comet's expulsive powers, at different times and distances. The nebulosity thus formed is not, however, an extension of the comet's nucleus, but discrete particles, which have no more claim to be called an atmosphere than the icy flakes of a snow storm.

From our present knowledge of cometary appearances we may say that every comet with a tail parts with matter at every perihelion passage, as Sir John Herschel indirectly suggested; but the loss of this matter may, perhaps (after the expiration of a sufficiently long period), enable the comet to settle down into more steady habits, and become, like Encke's comet, a law-abiding member of the system.

The office of this great radial stream cannot be estimated too highly. The same power which launches out a splendid tail at the rate of ten millions of miles a day, may, at the same distance and close to the same point in space, not disturb the moderately elliptical outline of the comet just mentioned. But if not at the perihelion,

where does this radial stream exhibit its greatest influence? Take the comet of 1843. It passed close to the sun—the sun then covering one-half its whole visible sky—yet it had a tail less than 1° in length, and in ten days afterwards it reached far beyond the earth's orbit. Another proof of the truth of our theory. At this time it was in that inner space of greatest condensation, which we have so fully entered into when discussing the question of the solar spots. There it became charged with the densest ether, that is, charged with positive electricity to the brim, then emerging into the planetary spaces where the density was less, the escape of ether carried up its lighter elements far beyond its proper superficial layers which thus became exposed to the strongest blast of the radial stream after the comet had gained a distance of a very few millions of miles from the sun. The denuding process than began afresh, and if the comet of 1880 was a return of the same comet, it is no wonder it lacked some of the splendors of its former appearance. But the *great* comet of 1882 was probably another comet.

The action of the radial stream will meet all difficulties in connection with the elementary peculiarities of a comet's composition and its own inherent energy. The varying length of the tails, the curvature of those tails, the multiplicity of the tails, their divergence from the plane and radius vector of the orbit, their intermitting activity and corruscations, their transparency to the light of the fainter stars, and those transient and abnormal rays which are sometimes emitted, as for instance, by Donati's comet, all represent the fitful vagaries of electricity. Now when we come to the question of change of diameter, the same efficient cause is equally responsible.

The smallness of a comet's mass insures a state of attenuation of its upper strata just verging on invisibility, so far as reflected light is concerned; yet it is this which to great depths contributes the greatest part of a comet's

diameter. Let this be so far attenuated by the escaping ether as to be driven off to form the tail, the diameter is immediately cut down while the radial stream elongates the nucleus into a prolate spheroid, whose axis is sensibly in line with the radius vector of the orbit. This still more diminishes the diameter of the nucleus, and this diminution depends on the force of the radial stream, which force increases enormously with diminution of distance. And, as we have just remarked, that it is characteristic of this stream to act spasmodically, like electricity generally, we can readily account for such changes as we have tabulated for Donati's comet. On October 5th the nucleus measured only 400 miles. On the 8th it measured 1,100 miles, but on the 10th it diminished again to 630 miles; yet the comet's distance was increasing on all those dates. If we have rightly represented the antagonizing currents of the solar vortex, when meeting at the sun, we need not be surprised if the outflowing current is fitful in the extreme, and never, perhaps, the same on different sides of the sun at the same time.

The reader can apply the theory to every observed peculiarity both in the motions and in the varied appearances of comets, and it will be strange if it be found incompetent to unlock the difficulty. But it may be said that it is not possible to reconcile this theory with meteor swarms composed of materials fit for macadamizing our highways. While it cannot be denied that solid rocks and iron stones have fallen upon the earth, yet the millions of meteors observed are far more likely to be composed of gases with viscosity enough to cohere, than of solid and heavy materials. If a comet be merely a collection of discrete fragments of rock, how can they remain united unless by a central force, and if so united how can they remain discrete? The prominent cometary phenomena which we refer to the agency of the ethereal medium, necessarily indicate the existence of a force which M. Faye and others call repulsive, and this repul-

sion they find in the solar rays. But where is the proof that the solar rays have such an effect, except by the expansion which heat produces? The undulations of the ether exert their force at right angles to the ray, and even in Crook's radiometer the action is no longer held by the inventor to prove solar repulsion. Even if proved, it would be altogether inadequate. The forces which underlie this question of the real office of the ethereal medium, are no pigmy forces, but titanic in its mightest sense, and the learned had better so regard it if they would make any further advances on these great questions. We therefore regard the speculations of Prof. Tait and Sir William Thomson as insufficient as those of Schiaparelli and others, who, while disclaiming the theory that comets are mere clouds of brick-bats (like Prof. Tait), yet contend that our meteor showers are somewhat similar to fragments of the comets dropped overboard, but following more tardily in the comet's wake.

No man who acknowledges that a comet's tail always points from the sun both on approaching and receding, will hesitate in regarding it as due to a force driving it away from the sun, as the wind drives away the smoke. It proclaims a truth which cannot be controverted, that it is something antagonistic to the force which compels a comet to move in a conic section. It is something which on such isolated particles is stronger than gravitation; for every particle of ponderable matter must obey that law, and it is obedience to that law which makes a comet's tail visible. The particle (not a brick-bat but a molecule of matter) resists being expelled, and continues to resist, and this resistance is what causes the light. The electric stream rushing past it acts as the current of our electric machines in passing through a partial vacuum, which we all know produces light, although there may be a very faint reflection as well. But M. Faye was not first in the field, even if we could not give a better reason for this repulsion.

Where then shall we turn for a theory if we reject the one herein developed? Newton's idea of vapor ascending from the comet in a contrary direction to the sun, necessarily implied the presence of a medium in space, contrary to his own hypothesis of a vacuum. Tyndall contended for chemical action, the flimsiest foundation of all to build upon, while M. Roche's mathematical method can only be regarded as auxiliary to Faye's theory of heat and gravitation, or repulsion and attraction, of which the first may be the strongest as exerted over minutely divided matter, while the last is most potent over matter in the mass.

Now there is one characteristic of our theory which the others do not possess. It explains (or professes to explain) all cometary phenomena on *one* common principle, and that principle elucidates many other difficult questions in physics. Other theories are content to limit themselves to one phenomenon, for instance, the formation of comet's tails, on some doubtful principle which is inadequate in nine cases out of ten, and contradicted by the requirements of kindred problems. Such theories have usually very short lives. Our theory *will live* much longer, for the time must come when competent judges will examine it. It may not be in this century; but we console ourselves with the adage

"*Magna est veritas et prævalebit.*"

CHAPTER X.

CONCLUSION.

In view of the magnitude and number of the questions we have presumed to embrace in our "Theory of Electric Vortices," we may perhaps be pardoned for recapitulating some of its most salient features, and the most prominent of those physical phenomena which are by its aid traced to simple mechanical principles.

We set out with the assumption that all space is flooded with an ethereal material fluid possessing that universal attribute of matter, inertia, yet imponderable. That there is, moreover, a standard of normal temperature, of normal density, and normal elasticity throughout its *infinite* extent. That there may have been a time in the past eternity when its mighty currents swept with overwhelming force around a shoreless universe, as it was in the beginning ere the dry land appeared above the surface of the waters in our own little world. That this motion of the ethereal medium existed long before the diffused ponderable matter collected in the numerous vortices necessarily produced by converging ethereal currents became centres of attraction, to become at a later stage centres of life when the word should go forth to each individual star, "Let there be light; and there was light." And that, therefore, the proper motions of the stars are not *solely* due to the attraction of a great central body, or to the resultant gravitating force of all, upon each individual star. But while each star does obey the general attraction, it is subordinate to the greater force, a mere aggregation of chips floating in the current of the great river of Eternity, as the drift of the

Amazon collects in vortices and eddies, in its passage to the Atlantic.

It is in this great ethereal ocean, co-extensive with infinite space, that we find an inexhaustible reservoir of kinetic energy which attests the omnipotence of Him who dwells therein. And while such a view elevates the mind by exalting the physical universe, of which we are a part, it seems, also, mercifully designed as a material guarantee to man, of the perpetuity and stability of the visible creation, subject to those changes which its connection with the spiritual world necessarily involves. For it is a consoling thought that there is no law of physical necessity which inexorably menaces the material fabric of the universe with final destruction and extinction as science is disposed to teach; but that there is enough and to spare of all that is needful for the well being of God's creatures in His great Store House, whose fullness was, is, and shall be, the same yesterday, to-day, and forever.

Further, we are justified by analogy and revelation in regarding the ponderable centres of stellar, planetary, and cometary nature as finite in number, although innumerable as the grains of the sea-shore sands. But into those questions of *when* the present state of things began, or *how far* the created universe extends, we shall not enter, but treat them as forbidden ground; for no practical benefit can be derived from their discussion.

On this foundation, then, we have built our theory, and have followed out these postulates to their legitimate inferences, and have shown that the key thus obtained fits the lock which has heretofore barred ingress into the vestibule of solar physics. But before dismissing that subject, it may be as well to recall to the reader's attention these prominent features of the theory:

1st. By rotation the solar vortex is rarefied, which originates a perpetual current of ether through the system. That, except at the centre (where the opposing currents meet, condense, give out their latent specific

caloric, and otherwise by friction keep the sun at its present temperature, varying with the displacement), the ethereal medium is at its least density in the interior of the solar vortex. But in consequence of this current there is a central core of greatest density, and that density becomes *greatest* around the axis. So that the part of the vortex where the ether is *least* dense is several solar semi-diameters from the axis, and from thence the rarefaction diminishes, following the law of the square roots of the distances from the axis, or (which amounts to the same thing) the density increases outward directly in the same ratio.

2d. That the solar spots are due to the displacement of the sun from the centre of the vortex, reaching their maximum when the displacement is at a maximum, and their minimum when the displacement is at a minimum; owing to the derangement of the sun's electric state by change of position in its orbit, as well as by change of position of portions of its equatorial zone by its rotation.

3d. That the solar corona and protuberances are due to the ether or electricity escaping from the sun, as well as to the sweep of the great polar currents, which last are rendered visible by passing through the attenuated matter carried up by the emanations from the body of the sun, and that these currents will account for all the peculiarities of the corona and for the zodiacal light.

4th. That we have purposely treated the electric fluid as we would the air we breathe; its positive or negative condition being but a question of density or intensity of pressure and elasticity reducible to mechanical principles and ignore all forces in the discussion of physical questions not reducible to such principles. The vital force and the force in man's will are questions we cannot reduce to intelligible mechanical principles, but in physical science there is no force but what arises from some form of matter put in motion (either kinetic or molecular) by

some other matter, and this is the true doctrine of the conservation of force.

No doubt the freedom with which we have spoken will offend, and there are many points in our theory which prejudice will cavil at, and it may be asked what proof do we adduce in support of our positions? To this we may triumphantly answer, the best of all proofs. We can appeal to facts of daily occurrence, which not only invite the savant but the most ignorant; not only do they invite, but demand in tones of literal thunder that both philosopher and peasant shall examine for themselves, whether it will not pay to give heed to the terrible warnings which the cyclone is so often giving, in its death-dealing visitations.

If we have succeeded in making out our case and shown such a correspondence between our theory and the solar phenomena it was devised to explain, then we have established a valid claim for *that portion* of our theory which relates to the electric vortices of our own globe, to be accepted as the most practically important truth of all. The poor hard-worked millions of the world care little for science. They gaze with wonder at a comet, at a total eclipse of sun or moon, they cower under the lightning-riven cloud, and shiver when winter assails them in their cheerless dwellings; but they care nothing for causes, unless such knowledge will help them to ameliorate their condition, and increase their comforts. Yet this is just the province of a true theory of the causes which disturb our weather, and which add energy to the cyclone and the hurricane. Until we begin to build upon a true foundation, all our weather reports and tabulated observations—the accumulations of years—are so much waste paper; yet governments are spending by the million to acquire facts which can never be utilized. But with a true theory of the weather we might soon enable the agriculturist, the navigator, the engineer, to diminish the percentage of loss from unfavorable seasons, from drouth

and floods, and also add to the comfort and health of every man, woman and child, whose pursuits require exposure to its changes.

Now, what we have again and again proclaimed, are stubborn facts; but in what language shall we again utter the truth to induce the world to receive it, or in what form can we put it to excite attention. There is here no concealed motive to ensnare the credulous, for their assent would accomplish nothing. It is a question for those with power and influence, for the truly scientific, and for the philanthropist. One single man against the world can do nothing but protest; and that protest cannot be heard by those whose ears are stuffed with vanity.

If the author of this theory were seeking for some substantial benefit through its reception—for wealth, or fame, or notoriety—then the world might receive with distrust his emphatic cry of *Eureka;* but none of these things are coveted. Let those who are willing enter the lists, and start from his standing-place, and labor for a tenth of the period that he has labored, with nothing but contempt and neglect for his reward, and his best wishes will go with them, that they may in thus benefiting the world, derive both honor and profit, even if they omit to mention the source from whence they draw their materials. But the wisdom of the world declares that what is offered freely without money and without price *must* necessarily be worthless. And so it may, perhaps, be always.

It is confessedly with a sad heart that the author places on record for the last time, this, his protest against the verdict which has been virtually pronounced, by those who claim possession of the key of knowledge.

The application of the theory of Electric Vortices as the chief disturbers of the state of equilibrium in our atmosphere is one which more extended observations can alone improve; but the author is tired of his harness.

The elements of the seven terra-lunar vortices are no doubt very nearly at their true value. At least their observed passages every few days verify them in latitude 30° N., which latitude is more favorable than a higher latitude for observation, on account of the fact that only two vortices are at the same time to the south of that latitude except on very rare occasions. It may be that the eastern coast of Florida where the present elements were determined is also in a favorable longitude, having the ocean on one side and not too large an area of land on the other. But in that latitude and longitude the passage of every vortex can be observed when once the observer is familiarized with the appearances, which are undoubtedly very variable, to which cause, the fact of the non-discovery of such a law for so long a time, may be attributed.

But this very fact renders the discovery the more valuable. If some buried fragment of antiquity were exhumed, and its record remained undecyphered for ages, but at last was found to be a record of vast importance to the world, surely the key to the interpretation would not be deemed of less value, because its interpretation had been given up for thousands of years. The world has always clung to the belief that we possess such a record in the moon; yet for want of the true key, no practical benefit has ever been derived from such a belief. But this theory offers the true key which no one can dispute; for it is endorsed every week and every month, and every year, to any one with common understanding who is willing to be convinced.

We thus repeat our statement in brief. The moon is by her mechanical action in displacing the earth the cause of all our atmospheric commotions; and that the seven electric vortices are continually following her in her sidereal revolution, and therefore in consequence of the obliquity of the vortex they all pass from their extreme limits north to the opposite extreme in both hemispheres. These limits are usually between 15° and 70°

but vary with the particular vortex, and with the parallax of the moon. The elements and formulæ for computing the passages of these several vortices are given, in full, in the Introduction, and with the aid of the Nautical Almanac, any one of these passages may be computed for any place and for any date, in the year for which the Almanac is published.

For middle latitudes a small error in the value of the elements will be more apparent than in latitude 30°, for the reason that the differences of latitude between the meridian passages of any vortex, is in latitude 50° twice as great as in latitude 30°; and therefore an error of half a degree in latitude 30° in the computed passage, will become a whole degree in latitude 50°, which, in fine weather, might give quite a different aspect to the sky.

In conclusion, the author would say, that it is impossible to exaggerate the importance of establishing the existence of these vortices; for they not only put us in possession of the great secret of the weather, but by their existence afford us a *visible* evidence of the existence of the ethereal medium, by the moon's agency in disturbing its equilibrium in the only way possible; thus proving its identity with what science calls ELECTRICITY.

From the author's experience he cannot expect any lenient verdict at the hands of science, even if this humble tribute to its treasury should not be again summarily rejected. But he does not look for its approval. Actuated by the conviction that a great truth has been committed to him, and warned by the approach of the Psalmist's second climax, he feels impelled to place the result of his life-long labors on record in its present compendious and imperfect form, in hopes that some of the seed thus sown may ultimately germinate, and bring forth fruit in proportion to its worth.

CHAPTER XI.

APPENDIX.

NOTE A.

The Electric Constitution of our Solar System. By Jacob Ennis. From the proceedings of the Academy of Natural Sciences, Philadelphia, for 1878. Philadelphia, 1878, pp. 19.

THE following extracts show the drift of this pamphlet :—"The zodiacal light, the aurora borealis, the corona of the sun, and the tails of comets, are all different forms of the same thing. They are electrical brushes, precisely the same as the electric brushes which in the night are seen to fly off from a highly charged electric machine. On the electric machine the electric fluid is developed by friction. On our great globe, on the sun, and on the comets, the electric fluid is developed by evaporation." . . . . "No one has said that the zodiacal light is electric, and that this and the auroral streamers, always, like comets, point away from the sun. No one has regarded all these phenomena as emanating from a common cause; the solar heat causing evaporation. No one has supposed that the far distant solar corona, by mere electric repulsion, drives off the tails of comets, the auroral streamers, and the zodiacal light. A highly charged electric machine affects a delicate electrometer far off on the opposite side of a wide room; but this wonder, until now, was not fruitful in originating our theory. Now, first, all those distant facts have been brought together, and they are seen to form a harmonious system" (pp. 3 and 19).

The writer of the above has published several works on astronomical subjects, but it has never been the author's lot to see any but the above extracts, which he read in the August number of the *Astronomical Register* for 1878. Now a writer who puts forth such large claims can scarcely be entitled to the plea of ignorance of what others have done, seeing that this theory of electric vortices was published by one of the foremost houses in the country in 1854 (delivered in 1853), and that it has since been repeatedly brought before the American Association for the Advancement of Science at Washington, at Montreal (1857), at Salem, at Chicago, at Nashville, at St. Louis, at Cincinnati, the Smithsonian Institution, and other scientific bodies. That it has been obtruded by circu-

lars on very many of the prominent names of science, and publicly stigmatized as of heretical character.

If the writer of that extract will peruse the Introduction to this volume he will perhaps see cause to modify his claims. As the author refers all electric effects to mechanical causes, so does he seek to reduce all physical phenomena to mechanical forces, intelligible to the unsophisticated mind. When we cannot explain an effect mechanically, we had better leave it untouched, until we obtain further light; for, otherwise, we shall be doing no better than our forefathers, who were satisfied that Atlas carried the world upon his shoulders.

NOTE B.

In the spring of 1881, the author addressed a letter to the Secretary of War, under whose authority Congress had decided to send out an expedition to the Arctic regions to establish a meteorological station and colony in Lady Franklin Bay, in the channel dividing Greenland from the continent. This presented a rare opportunity for testing the theory in a high latitude, perhaps to the north of the turning-point of some of these electric vortices, and thus correcting at least one element of their orbits.

In that letter he asked permission to communicate with Lieut. Greely, who was selected to command the expedition, in order to impart to him the mode in which such a question might be decided without entailing any inconvenience or impairing the value of other observations. In answer, he was referred to the Chief Signal Officer at Washington, Brig. and Bvt. Major-General W. B. Hazen, whose answer is as follows:

WAR DEPARTMENT,
OFFICE OF THE CHIEF SIGNAL OFFICER,
WASHINGTON, *April 27th*, 1881.

MR. THOMAS BASSNETT,
Jacksonville, Fla.
(Through Hon, W. Call, U. S. Senate).

DEAR SIR,—

Your letters of April 14th to the Hon. Secretary of War and the Hon. Wilkinson Call (U. S. Senator), and also yours of April 18th to the Hon. Secretary of War, all relative to certain meteorological theories, and especially to certain observations that you desire to be made in the Arctic regions by Lt. Greely, have been referred to this office for reply.

In reference thereto, I have the honor to say, that I desire in every way to advance our knowledge of the laws that govern storms and other movements of the atmosphere, and will give unbiased consideration to any reasonable and practicable plans that you may suggest, as to new methods or objects of observation; but as our work is done for the benefit of the public, and must be fully published for the criticism and use of the world,

it will obviously be improper for this Department to receive "specific instructions under the seal of honorable confidence guaranteed and indorsed by this Department."

I am very respectfully,
Your obedient servant,
W. B. HAZEN,
Brig. and Bvt. Maj.-Gen'l,
Chief Signal Officer U. S. A.

The offer, to furnish Lieut. Greely with the elements of the theory and the tables and formulæ necessary to apply them, as well as to give a full explanation of what peculiar features of the weather it was most advisable to observe and of the object of such observations, was declined, and excepted to, as it would "obviously be improper to receive specific instructions under the seal of honorable confidence guaranteed and indorsed by this Department." The author's wish to stand acquitted of the charge that he had failed in presenting his views on an occasion which might never return—views, which he believed of so much importance as to constitute the *only* key calculated to unlock the chief mystery in meteorology —ought to justify the placing these matters on record.

In answer to this decision he explained that his meaning had not been fully understood, and that "In reference to the observations which might be made in the Arctic regions, I consider it a great pity that such an opportunity should be lost; but I see no alternative but to accept the situation and be resigned. I thank you for the assurance your letter contains that you will give 'unbiased consideration to any reasonable and practicable plans you (I) may suggest,' and in consequence have concluded to attempt a condensation of my system into a brief but very meagre outline of what I claim to have discovered; with such explanations as seem actually necessary to make the question intelligible to those to whom it is yet unfamiliar. You will then be able to judge how far you may deem it proper to commit yourself in adopting any suggestion I might make with reference 'to new methods or objects of observation.'"

After giving a general account of the preliminary questions and principles involved and "the dark and devious path I had to travel before reaching a region free from obscurity," I announced the conclusion arrived at, "that the ancient belief in the moon's influence over the weather was a truth; but not as usually interpreted by assigning that influence to the lunar phases, which would render it necessary to admit a similar state of things, at the same time, in all parts of the world." and that the "ever changing phases of the weather are due to the motions of seven vortices in the ethereal medium," fully developing their mode of action and showing them as "adequate causes to explain the concurrence of storm and calm in localities not remotely distant. and at intervals corresponding to the astronomical laws governing the moon's motions."

The communication is too long to be inserted here and reference to its

character is all that is needed as a record; but it has been deemed best to give the concluding passage on account of the two examples of its application accompanying that communication. These refer to a storm which the Signal Office tracked from Kansas to Washington, from the 27th to the 30th of March, 1881, and considered a remarkable confirmation of the belief that storms continued their existence for a long period (an error which clogs the investigation into the cause or origin of storms). The computation was sent on and the disturbances shown to be due in Kansas, Kentucky, and Washington to three independent vortex passages, in the latitudes where they were observed to be violent.

"With this I send a computation of some passages compared with such notes of the weather as I have been able to obtain; but emanating from the Chief Signal Office in Washington, and regarded, as I am informed, as a remarkable case of successful tracking of a storm from its entrance to its exit. In conclusion, I beg you to submit this communication to the Hon. Sec. of War for his information in the premises, with the request* that I may be made a recipient of the maps and charts published by the Signal Office, either to be paid for or otherwise as may be deemed proper, as I feel confident that I can take plotted tracks and latitudes of the principal storms, and show by the same computations, that the elements on which these computations are based, are but the expression of stubborn facts, which are applicable to the computation of *all* storms which have been correctly recorded."

I have the honor to be, Sir,
Very respectfully,
Your obedient servant,
THOMAS BASSNETT.

NOTE C.

COMMUNICATION.

Dated JACKSONVILLE, FLORIDA, *Dec.* 21*st*, 1882.

Sent to the Transit of Venus Commission, at Washington, D. C.

Long. of telescope—W. 81°—37′—0″.
Lat. of telescope—N. 30°—18′—10″.
Aperture of telescope—5¼ inches. H. Fitz, maker.
Focal length of telescope—7 feet. Equatorially mounted.
Power used during transit—120.
Eye-piece—Ramsden, by Alvan Clarke.
Position Micrometer, by Alvan Clarke.

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* In answer to my request I was furnished with a circular of the scale of prices of those publications, but must plead guilty of negligence in not availing myself of the privilege.

Herschellian solar eye-piece, by Alvan Clarke.

Watch—Elgin Raymond, No. 35,224.

Telescope levelled and firm on Meridian, from Alpha Polaris, at its transit, Dec. 5th.

Darkening glass of London smoke, by A. Clarke.

Telescope clamped in Declination and focused on fine spider lines.

Full aperture used during Transit.

Telescope moved by a string to avoid tremors from pulsation of body. Hand rod rejected.

Venus followed the central line throughout.

Assistant to note time, Mrs. T. Bassnett, who counted seconds some time before contacts. At the word "Mark" she noted the time, then added any brief comment made.

"Depending too much on the tabular position angle at ingress, and being too anxious to discover Venus, I confined my gaze to too small an arc. When the planet was first seen it had already notched the limb; the time was estimated at one minute and some seconds, perhaps one minute roughly. The watch by which the contacts were noted, was rated for two months previously, showing an uniform loss of 6.5 seconds per day. On Dec. 4th, I called at the telegraph office, but for want of timely notice and the clicking of three other instruments, I failed to get a reliable result. On the 5th and 7th of Dec. no time was received from Washington. I then went to St. Augustine, and by the politeness of Major Bassot of the French Transit party, and of Mr. E. D. Preston of the U. S. C. S., who acted as interpreter, and kindly reduced his sidereal time to mean time, I found watch rate 6s. per day or 5s. during the time elapsing between comparisons. From these comparisons I found my watch was — 3m. 12.5s. on the day of the transit for middle time, and therefore at watch time of first contact—3m. 13s."

TRANSIT OF VENUS, DEC. 6TH, 1882, JACKSONVILLE, FLA.

Watch in local time		— 0h.	3m.	13s.
Longitude West of Washington		+ 0h.	18m.	16s.
Difference compared with Washington		+ 0h.	15m.	3s.
Making in	1st Contact	8h.	55m.	37s.
Washington	2d Contact	9h.	15m.	43s.
Mean	3d Contact	2h.	40m.	28s.
Time	4th Contact	8h.	1m.	1.5s.

1*st Contact.*—If the first indentation had not been lost, this contact would have been excellent; for although there was a little scattered cirrus, the sun shone out bright when the notch was seen at

Watch time.....	8h.	41m.	34s.
Estimated past contact	0h.	1m.	0s.
Perhaps before but *not* after.....	8h.	40m.	34s.

2*d Contact.*—This was also well observed and by comparing the two limbs a closer contact was obtained as the curve of tangency was through the middle of a short ligament.

This was at 9h. 0m. 40s.

Previous to the 2d contact the south following limb of Venus for a full quadrant, was very conspicuous when half of the planet was outside the sun. It was much wider on the part of the limb in contact with the sun, than 90° from it, and the other quadrant showed very little margin. But there was another feature observed. The lower outline of the bright arc was not in contact with Venus, but described the arc of a larger circle by a full second of arc.

3*d Contact.*—This was made through clouds and was not as good as the 2d contact. The time noted was perhaps in excess a very few seconds.

Time per watch, 2h. 25m. 25s.

Between the 3d and 4th contacts clouds prevented the atmosphere of Venus being seen; but at the *4th Contact*, only a thin stratum of cirrus intervened, rendering the sun and Venus beautifully defined without darkening glass. The atmosphere of Venus was, however, completely obliterated, and nothing more was seen of it. Time of contact by watch was 2h. 45m. 58.5s.

NOTE D.

A copy of the circular referred to is appended below. A verbatim copy is given: for the author is not ashamed that a theory covering such a wide field should require time for the correct application of its principles, and for the true interpretation of observed facts. Therefore, if during the last fourteen years the first interpretation has been modified as new facts have been discovered, it is but in accordance with the general law of progressive stages in the gradual development of human knowledge, especially in the department of natural philosophy. The fundamental propositions of the Theory in all its parts remain as published thirty years ago, and are enunciated in private correspondence of over forty years. If, then, the precise *modus agendi* of the force produced by the rotation of the medium which surrounds the sun has been rendered more intelligible and demonstrable by a better interpretation, no valid objection can be raised against the integrity of the theory on that account. It really constitutes an additional buttress against the assaults of an

illiberal criticism. If, in the seclusion of his Western home, he was not promptly advised of the interest suddenly awakened about 1840 on the subjects he had presumed to investigate, it was owing to the narrow circle irradiated by the journals devoted to science, and the little interest felt in those subjects by all except the few whose pursuits were professionally scientific. Much which is now commonplace was then just emerging into the light, and there seemed no other way open to one craving for some rational explanation of the causes to which such wonderful effects as nature exhibits, both in the earth and in the heavens, are due, but to endeavor to think them out for himself, and if he cired "Eureka" too loudly, it was only a fault which has been frequently committed since by the most orthodox tribunals of matured philosophy. Less than twenty years ago much stress was laid on the actinism of the ultra violet rays of the spectrum, and the co-existence of three separate curves of heat, light and actinism, which represent the thermal, luminous and chemical rays. But Prof. Langley, whose authority on the spectrum few will question with his sensitive apparatus for measuring the solar energy, says in his paper published in the appendix to Prof. Young's "Sun:" "We can already, though, see here that there is nothing corresponding to the so-called actinic curve whatever. Precisely where it is represented at its maximum in the ultra violet the real energy is nearly at its minimum. The special sensitiveness of certain salts of silver then to these radiations—not any special energy in the radiations themselves—led to the former quite mistaken belief that there was something here called actinism or chemical force, and to the belief still entertained (and also a mistake) that there is any considerable energy in this ultra violet part, as we receive it to be interpreted by photography or any other way." It is true Prof. Langley requests the reader "to remember that what he now reads has not yet become part of the body of accepted scientific fact, but rests on (his) own statement of opinion."

A few years ago it would have been regarded as the rankest heresy to question the general interpretation of certain results of spectroscopic observations, but there is a growing feeling of uncertainty regarding them arising from a more thorough cross-questioning of the very instrument, on whose testimony the supposed laws were founded. Mr. Proctor (in his "Sun," page 432) says: "It had been supposed that the whiteness (or true incandescence) of flame was due to the presence of minute particles of incandescent matter. But Frankland has shown that with increase of pressure the faintly luminous light of burning hydrogen may be rendered bright, and that by sufficiently increasing the pressure the spectrum of the light becomes continuous. So that what had been supposed the most marked characteristic of incandescent solid and liquid bodies is thus shown to be a possible characteristic of the light of glowing gas. Thus the whole basis of our reasoning (which had been thought so sound) respecting the actual condition of the solar photosphere, whether as evidenced by direct observation or by analysis with the spectroscope, has

been shaken." But he even admits that men of science "have learned of late to recognize on how very doubtful a basis *many* of the received axioms of physical science have been placed." Such facts being admitted, the author need offer no apology for the plainness of his language in the circular copied below, or for the imperfect application to existing phenomena of those principles therein enunciated, which were from the beginning so pregnant with important developments.

The computed fact to which attention was then drawn, viz., the angle under which the centres of the sun and of the corona would appear from the earth, and of the distance of those centres on the day of eclipse, will be found more accurately computed in Table IV.—the earth's longitude at the time being 315° 23′, and that of the sun 135° 23′.

CIRCULAR.

SIR:—From 1840 to 1854 the subscriber brought to the notice of several of the scientific organizations of the day a theory of Storms and general Physics, which involved the recognition of the mechanical nature of all natural phenomena; but the verdict placed the theory under a ban which only a few had the hardihood to disregard, and hence as the author's profession was independent of science, he concluded to wait and watch until further progress should take away the great reproach of being "ahead of the times"—a charge gravely made against him by one such organization.

Nevertheless, during the long years which have intervened the author has not been unobservant of the gradual approximation which various learned theories, either kindred or derivative, have been making to those views published in 1853, ignorance of which can scarcely be pleaded as a reason for withholding all reference to them.

But the object of this communication is not to obtrude that theory again on unwilling ears, but to suggest to all those who contemplate observing the great solar eclipse of August 7th, that it can do no harm to science, to assume for the time being the truth of certain postulates, by the light of which the observed facts may be interpreted rationally, if those particular facts *should* be observed. As this is a rare occasion, he feels justified in addressing you, and, to be brief, he will assume as true the following features of his theory: Space is filled with matter in motion throughout all its infinite extent, and the light and heat of the remotest star reaches us through its eternal undulations. This medium possesses inertia without gravity, and can interchange with all other matter the motion which it possesses, whether vibratory or of the nature of heat or translatory; and as the force or momenta of all matter susceptible of such interchanges must be equal, it follows that the specific heat of the ether far transcends that of ponderable matter, and this feature of the theory lies at the foundation of many grave questions in physics. The translatory motion of the ether, as measured by the peri-

odic times of the planets, begets a centrifugal tendency within the solar system that causes rarefaction instead of condensation at the centre, which is another peculiar feature of the theory having very important bearings, as it is the cause of the polar currents down the axis of the fluid vortex surrounding the sun—there meeting and thence being deflected along the equatorial plane, restoring or tending to restore the equilibrium. These polar currents meeting at the sun constitute a perpetual source of heat and light; or, in the language of the theory, the translatory motion of these currents "will be converted into atomic motion or heat, according to the motion lost by the resistance of atomic matter."* Thus the solar fires may be replenished by agencies which neither add to the diameter of that body nor diminish the small amount of meteoric matter in the solar system, which, analysis demonstrates, is not sufficient for a year's supply of fuel. But if not resisted, or only partially resisted, this ethereal medium, having the frigid temperature of space, may cause condensation of highly heated gaseous matter, and form cloudy spots in the solar atmosphere when the sun is sufficiently forced out from the axis of the vortex to allow the polar stream to strike the surface very obliquely, hence these spots are found only in latitudes where this obtains. As the great planets revolve the sun's longitude varies from year to year, and the distance of his centre from the axis of the solar vortex varies also. And this period was *first* presented by this theory as the period of the solar spots, of terrestrial magnetism, and of the weather cycle; and to this cause (the revolutions of the great planets) many scientific authorities seem disposed NOW to attribute the result, in all three cases above specified. Yet, while this period is observed, there are subordinate influences at work which prevent an EXACT recurrence of the same phenomena. Different years do actually vary in mean temperature, and the mean solar radiation varies. Yet different years may and do vary in their seasons when the mean annual temperature is the same; but the position of the sun with respect to the dynamical axis of the solar vortex, and its distance from that axis is, no doubt, the chief element of the change, and hence the practical importance of the question.

The present year again verifies the theory. The spots are near the maximum; the polar current strikes the sun's surface in its most favorable position; the weather confirms the testimony of the sun, and the magnetic needle and the earthquake corroborate it.

It now only remains for the coming Eclipse to put its seal to the verdict. At the time of the Eclipse, the centre of the system (allowing for the action of four planets) will form very nearly a right angle with the earth and sun, which position will be very favorable, as the course of the ethereal stream will be exhibited in profile, the body of the sun offering an obstruction on one side, while on the other the passage

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* See "Outlines," p. 173.

will be free. In other words, the mass of light may be expected to be more diffused, more regular, but not necessarily more intense during the total phase on the preceding side, and the coronal rays more irregular in intensity and direction on the following side; and it is to this anticipated difference that your attention is respectfully invited,—not limiting observations to the immediate margin of the moon and corona, but extending them for several diameters on every side, although it is probable that the stronger light of the margin may extinguish much of what would otherwise be visible. If the coronal rays are due solely to light reflected from a highly attenuated atmosphere of planetary matter, its diameter should be quite limited and its margin well defined and perfectly concentric with the sun. If, on the other hand, it is due to the cause assigned, it should visibly respect the axis of the vortex, although the position of this axis can only be assumed as probably parallel to the pole of the ecliptic. On the day in question the axis will be over 870,000 miles from the sun's centre, reckoning as before, only four planets, at which time spots should be seen in the northern hemisphere in higher latitudes than in the southern, if the position of the axis of the vortex is rightly assumed. THOMAS BASSNETT.

OTTAWA, *July 20th*, 1869.

NOTE E.

ORIGIN OF SOLAR HEAT.—SIR W. THOMSON'S THEORY.

SOME very important speculations have been brought forward on the *source*, and thus bear on the *nature*, of the solar heat, by Sir W. Thomson, in immediate connection with the theory of Joule, and on the principle that the energy of the heat thus emitted, must be accompanied by an equivalent expenditure of mechanical force. On this principle he institutes numerical calculations, the main results of which, together with a brief exposition of the principles, may be given as follows:

The kind of force acting, or the source of solar heat, the author (Sir W. Thomson), conceives may be expressed by several hypotheses, each of which he examines:

I. The supposition of the sun being a body intensely heated and losing its heat by radiation or simple cooling.

This he considers quite untenable, as well on theoretical grounds advanced in some other papers, as on the simple consideration that if this were true the sun would be extinguished in a very short time.

II. The hypothesis of chemical action or combustion of any kind.

Supposing one of the combining bodies to be supplied from any atmosphere, the products of combustion would be so enormous as to choke the fire, if gaseous, by preventing the access of the air in question, or, if solid or liquid, by preventing the supply of fuel; and according to the

mechanical theory before mentioned, a numerical calculation shows that the whole mass of the sun could scarcely last 8,000 years without being all consumed, if generating, by its own burning, the heat which is actually emitted. Hence, if the sun is a fire, the fuel must be supplied from external space. But a mass of coal or iron or potassium could not reach the sun from external space without generating thousands of times as much heat from its motion as it could possibly do by its combustion. Combustion is probably, therefore, insignificant, if it exists at all, as a source of solar heat.

III. The hypothesis of meteors falling into the sun and expending force *mechanically* has been started by Mr. Waterston, who supposes such bodies to be attracted and fall directly into the sun from remote *extra-planetary* regions.

The supply of meteoric matter necessary, according to this theory, is estimated to amount to such a mass as would cover the sun's surface to a depth of thirty feet in one year.

The author, however, considers it probable that meteors actually fall into the Sun, not directly from distant spaces, but by the action of a resisting medium surrounding the sun, which *contracts* the orbits in which they are revolving around him. He conceives that these meteors must be moving *within* the limits of the earth's orbit, or we should be continually struck by them, and that they are probably the matter of the zodiacal light.

It is, however, quite conceivable that that cloud of small planetary masses may once have extended beyond the limits of the earth's orbit, and thus in remote periods the earth may have been exposed to such falls of them as to have materially raised its temperature ; and hence a possible source of those high temperatures which once existed.

But to return to the effects of the resisting medium. Owing to its retardation, the approach of these bodies to the sun is gradual, and on this hypothesis a calculation similar to the former would give the result that the sun must be covered to a depth of sixty feet in a year, or a mile in about eighty-eight years, which would occasion an increase of 1″ apparent diameter in 40,000 years—a change, of course, utterly inappreciable to observation.

The amount of matter thus abstracted by the sun would be equal to the mass of the earth in about forty-seven years ; but it is quite conceivable that a quantity of one hundred times this amount would not be missed from the zodiacal light. Thus the sun's heat might be kept up for five thousand years to come at least. This transfer of matter to the sun coming from a source within the earth's orbit would not affect the conditions of the system as to the effects of gravitation.

Some meteors may possibly come direct on the sun from the extra planetary spaces, but the quantity of such is probably very small in comparison with those that have been revolving in approximately circular or elliptic orbits before falling in.

If we imagine a dark body moving through space and coming into a locality abounding with meteors, their impact may raise it to incandescence, which will cease when it moves out of that space. Thus the author suggests a possible explanation of variable stars.

(Addition I.) The author gives a calculation of the quantity of matter necessary to be added to the sun on the *extra-planetary* hypothesis, and finds it gives too great an increase of central force to consist with the historical conditions of the earth's motion. He concludes the supply must have been from *within* the earth's orbit for thousands of years at least.

(Addition II.) He shows that the resistance must be very small even close to the sun, since such light bodies as comets pass through it at perihelion.

The solar atmosphere may be conceived to be carried round in a vortex by these revolving masses, but not more rapidly than a planet would be at the same distance. Hence the meteors must long continue to revolve before reaching the sun, *and must get so near as to be completely evaporated before they fall in.*

Hence the solar heat is produced, not by solids impinging on the sun, but by the violent friction of the rotating vortex of evaporated meteoric matter.

(Addition III.) The temperature of the different parts of the sun's surface may undergo great changes from the eddies and streams occurring in this revolving mass. Hence many of the appearances of the solar spots and streaks, etc.

(Addition IV.) "On the age of the Sun." At the rate of meteoric incorporation above calculated, the present rotation of the sun would be produced from rest in thirty-two thousand years. We may infer (since it appears very improbable that the sun has had a contrary rotation destroyed by meteoric incorporation) that the kind of agency now going on cannot have been going on, and alone generating heat at the present rate for more than that period. For the future, we know that the mass of the zodiacal light is small in comparison with that of the sun, from its producing no sensible perturbation on the planets, and we may be sure it cannot keep up the supply for three hundred thousand years. The sun's rotation has been by no means accurately determined; it may possibly vary to an amount which future observations may detect, and thus test the theory. (See Transactions of Royal Society of Edinburgh, vol. xxi. part 1.)

NOTE F.

At a general meeting of the American Association convened at Nashville, the author presented the following resolution:

"Resolved, that in the opinion of this Association the Superintendent

of the "Nautical Almanac" would facilitate researches in the uncertain domain of physical astronomy, by giving a column on one of its pages, showing the systematic longitude of the sun's centre and the values of the radius vector for the first day of each month (or oftener at his discretion), as computed for the action of the four great exterior planets, and that the Permanent Secretary be instructed to present this resolution at the close of this Convention." (See Proceedings of A. A. A. S., Nashville Meeting, page 385.)

This was duly seconded by another member, the Hon. Wm. Bross, of Illinois, but the then president put his foot emphatically down upon the resolution, declaring, "that what the mover wanted, was not only done for every month, but for every day in the year." Not wishing to be the instigator of an unseemly discussion, the author did not retort, except by quietly informing the president that he did not understand the resolution he was condemning. Nevertheless, the author feels grateful to him, as he then resolved he would not again be placed in the same unpleasant predicament, and the consequence is that, instead of these necessary details for a few years, he is now enabled to lay before his readers the rectangular co-ordinates of the sun's centre for 100 years of past time, and 20 years of future time, with all the necessary precision for the purposes here intended; and to the amateur who requires such data in his pursuits, our Table II. is alone worth the price he may pay for this volume. When will the time come when men drest in a little brief authority will cease to arrogate to themselves the monopoly of superior wisdom?

NOTE G.

As the elements of the terra-lunar vortices assumed a settled value a correction was found necessary in addition to the changes due to the varying parallax of the moon, whose co-efficient was found, from observation, between .02 and .03 of the earth's mean radius. Subsequently it was traced to its origin, and a more correct co-efficient obtained. This correction arises from the law of density in the solar vortex, as will be better understood by the following diagram.

Let the circle P, E, R, I, represent the circumference of the terra-lunar vortex, and C, the centre. Let this be divided by the diameter P, R, into two semi-discs whose centres of gravity may be roughly taken as $\frac{2}{3}$ of the semi-diameter from the base = the lines C, G, and C, g (the correct quantity given by the calculus is .4114 of the semi-diameter where a semi-disc is of uniform density). Now, as the density of the ether is as the square roots of the distances S, G, and S, g, we see that the semi-disc G must be denser and therefore have more inertia than the semi-disc g, and therefore the vortex cannot be in equilibrio by rotating around the centre C. In order to be balanced the centre of gyration must be in the line divid-

ing the circle into two unequal segments whose inertia shall be equal. The required co-efficient of displacement gives 108 miles as the amount taken from the segment *G*, and added to the segment *g*, to make a balance in the system ; so that the centre of rotation is no longer at *C*, but at *c*, while the centre of gravity of the earth and moon will be at *C* and *P*, *C*, *R*, will be the line of the terra-lunar orbit.

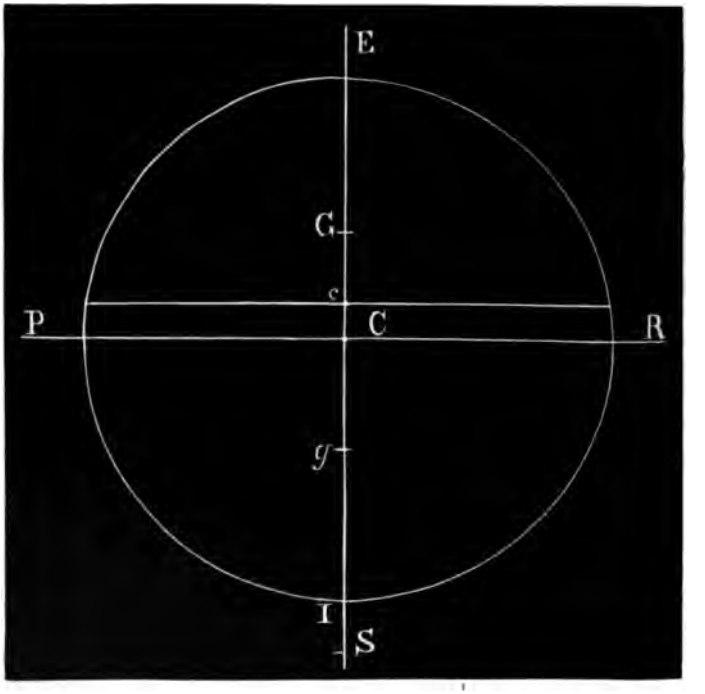

FIG. 27.—DISPLACEMENT OF CENTRE OF GRAVITY OF THE TERRA LUNAR VORTEX, BY THE LAW OF DENSITY OF THE ETHEREAL MEDIUM.

Now if we can deduce from our observed displacement, a value for the semi-diameter of the vortex, extending as far as the moon (as that body is a part of it), we may reasonably infer our observed displacement is not far from the truth.

A little variation in the solar parallax will not much affect the result, so we will take the mean distance of the sun as first calculated (= *S*, *C*,) as 92,250,000 miles and call it *a*. Then consider *x* as this distance + the line *C*, *G*, and as we know the value of the displacement, *d* = 108 miles, the following equation will represent the problem :

$$x - a = \frac{d}{2}\left(\frac{\sqrt{a}}{\sqrt{x} - \sqrt{a}}\right)$$

As this cannot be solved generally, we can assume the value of x, and by repeated trials, we get the distance $C,G = 100{,}000$ miles; but 100,000 miles is given as $\frac{2}{5}$ of the semi-diameter of the whole vortex, which, therefore, is equal to 250,000 miles or 10,000 miles greater than the moon's mean distance, and, consequently, the observed displacement is probably near the truth.

This displacement then introduces the term $d = .036 \cos (☾ - ☉ + 90°)$ into the equation for latitude, and $D = 2' \sin (☾ - ☉)$ into the longitude; all which can be readily put into convenient tabular form as well as all the other corrections, so that it need not take over ten minutes to compute the latitude and longitude of any vortex passage for any given time and for any locality in either hemisphere of the globe, with the aid of the Nautical Almanac and the common logarithmic tables. The elements are tabulated in the Introduction and the corrections below.

DISPLACEMENT IN LATITUDE.					DISPLACEMENT IN LONGITUDE.				
☾ − ☉		d	☾ − ☉		☾ − ☉		D	☾ − ☉	
°	°		°	°	°	°	° ′	°	°
− 0	+180	.036	+180	−360	+ 0	+180	0.00	−180	−360
5	175	.036	185	355	5	175	0.10	185	355
10	170	.036	190	350	10	170	0.20	190	350
15	165	.035	195	345	15	165	0.31	195	345
20	160	.034	200	340	20	160	0.41	200	340
25	155	.033	205	335	25	155	0.51	205	335
30	150	.032	210	330	30	150	1.00	210	330
35	145	.030	215	325	35	145	1.09	215	325
40	140	.028	220	320	40	140	1.17	220	320
45	135	.026	225	315	45	135	1.25	225	315
50	130	.024	230	310	50	130	1.32	230	310
55	125	.021	235	305	55	125	1.38	235	305
60	120	.018	240	300	60	120	1.44	240	300
65	115	.015	245	295	65	115	1.48	245	295
70	110	.012	250	290	70	110	1.53	250	290
75	105	.009	255	285	75	105	1.56	255	285
80	100	.006	260	280	80	100	1.58	260	280
85	95	.003	265	275	85	95	1.59	265	275
90	90	.000	270	270	90	90	2.00	270	270

While the computation of the passage of a vortex is strictly an astronomical problem, yet there is no necessity for taking account of second differences. In fact, mean values are all that is at present practicable in applying corrections. The symbol p is one of the corrections for time,

due to the inclination of the vortex plane to the earth's equator, and is a plus correction for a descending passage, and a minus correction for an ascending passage. Its co-efficient is 100 minutes, by which quantity the vortex comes to the meridian at a descending passage before or after that point on the ecliptic indicated by the vortex longitude. The argument is cos b, b being one of the given quantities in the general formula exemplified on page xxxvii of the Introduction. This correction we call Primage.

PRIMAGE $= p = \pm$ 100m. cos b.

b =		b =		b =	
	h. m.		h. m.		h. m.
0°	1.40	35°	1.22	70°	0 34
5	1.40	40	1.17	75	0.26
10	1.38	45	1.11	80	0.17
15	1 36	50	1.04	85	0.09
20	1.34	55	0.57	90	0.00
25	1.30	60	0.50		
30	1.26	65	0.42		

NOTE H.

"The planetary arrangements of the solar system are all *a priori* indications of the theory of vortices, not only by the uniform direction of the motions, the circular orbits in which these motions are performed, the near coincidence of the planes of these orbits, and the uniform direction of the rotation of the planets themselves; but, also, by the law of densities and distances, which we have already attempted to explain. In the motions of comets we find no such agreement. These bodies move in planes at all possible inclinations, in orbits extremely eccentrical and without any general direction—as many moving contrary to the direction of the planets as in the opposite direction; and when we consider their great volume, and their want of mass, it appears, at first sight, that comets do present a serious objection to the theory. We shall point out, however, a number of *facts* which tend to invalidate this objection, and which will ultimately give the preponderance to the opposite argument."

"Every fact indicative of the nature of comets proves that the nuclei are masses of material gases, similar, perhaps (at least in the case of the short-period comets), to the elementary gases of our own planet, and consequently these masses must be but small. In the nascent state of the system, the radial stream of the vortex would operate as a fan, purging the planetary materials of the least ponderable atoms, and, as it were, separating the wheat from the chaff. It is thus we conceive that the av-

erage atomic density of each planet has been first determined by the radial stream, and, subsequently, that the solidification of the nebulous planets has, by their atomic density, assigned to each its position in the system, from the consequent relation which it established between the density of the ether within the planet, and the density of the ether external to it, so that, according to this view, a single isolated atom of the same density as the mean atomic density as the earth could (*ceteris paribus*) revolve in an orbit at the distance of the earth, and in the same periodic time. This, however, is only advanced by way of illustration."

"The expulsive force of the radial stream would thus drive off this cometary dust to distances in some inverse ratio of the density of the atoms; but, a limit would ultimately be reached, when gravitation would be relatively the strongest, the last force diminishing only as the squares of the distances, and the first diminishing in the compound ratio of the squares and the square-roots of the distances. At the extreme verge of the system, this cometary matter would accumulate, and, by accumulation, would still further gather up the scattered atoms—the sweepings of the inner space—and, in this condensed form, would again visit the sun in an extremely elongated ellipse. It does not, however, follow, that all comets are composed of such unsubstantial materials. There may be comets moving in parabolas, or even in hyperbolas—bodies which may have been accumulating for ages in the unknown regions of space, far removed from the sun and stars, drifting on the mighty currents of the great ethereal ocean, and thus brought within the sphere of the sun's attraction; and these bodies may have no analogy to the periodical comets of our system, which last are those with which we are more immediately concerned."

"In 1770, Messier discovered a comet which approached nearer the earth than any comet known, and it was found to move in a small ellipse with a period of five and a half years; but although repeatedly sought for, it was the opinion of many that it has never been since seen. The cause of this seeming anomaly is found by astronomers in the disturbing power of Jupiter—near which planet the comet must have passed in 1779, but the comet was not seen in 1776 before it passed near Jupiter, although a very close search was kept up about this time. Now there are two suppositions in reference to this body: the comet either moved in a larger orbit previous to 1767, and was then caused by Jupiter to diminish its orbit sufficiently to give it a period of five and a half years, and that after perihelion it recovered a portion of its distance in endeavoring to get back into its natural orbit; or if moving in the natural orbit in 1770, and by passing near Jupiter in 1779, this orbit was deranged, the comet will ultimately return to that mean distance, although not necessarily having elements even approximating those of 1770. In 1844, September 15th, the author discovered a comet in the constellation Cetus (the same previously discovered by De Vico, at Rome), and from positions *estimated with the naked eye*, approximately determined the form of its orbit and its periodic

time to be very similar to the lost comet of 1770. These conclusions were published in a Western paper, in October, 1844, on which occasion he expressed the conviction, that this was no other than the comet of 1770. As the question bore strongly on his theory, he paid the greater attention to it, and had, previously to this time, often searched in hopes of finding that very comet. Since then, M. Le Verrier has examined the question of identity and given his decision against it; but the author is still sanguine that the comet of 1844 is the same as that of 1770, once more settled at its natural distance from the sun. This comet returns to its perihelion on the 6th of August, 1855, according to Dr. Brünow, when, it is hoped, the question of identity will be reconsidered with reference to the author's principles; and, that when astronomers become satisfied of this, they will do him the justice of acknowledging that he was the first who gave publicity to the fact, that the 'Lost Comet' was found."

"That comets do experience a resistance, is undeniable; but not in the way astronomers suppose, if these views be correct. The investigation of Professor Encke, of Berlin, on the comet which bears his name, has determined the necessity of a correction, which has been applied for several returns with apparent success. But there is this peculiarity about it, which adds strength to our theory: 'The Constant of Resistance' requires a change after perihelion. The necessity for this change shows the action of the radial stream. From the law of this force (reckoning on the central plane of the vortex), there is an outstanding portion, acting as a disturbing power, in the subduplicate ratio of the distances inversely. If we only consider the mean or average effect in orbits nearly circular, this force may be considered as an ablatitious force at all distances below the mean, counterbalanced by an opposite effect at all distances above the mean. But when the orbits become very eccentrical, we must consider this force as momentarily affecting a comet's velocity,—diminishing it as it approaches perihelion, and increasing it when leaving the perihelion. A resolution of this force is also requisite for the comet's distance above the central plane of the vortex, and a correction, likewise, for the intensity of that force estimated in that plane. There is also a correction necessary for the perihelion distance, and another for the tangential current; but we are only considering here the general effect. By diminishing the comet's proper velocity in its orbit, if we consider the attraction of the sun to remain the same, the general effect *may* be (for this depends on the tangential portion of the resolved force preponderating) that the absolute velocity will be increased, and the periodic time shortened; but after passing the perihelion, with the velocity of a smaller orbit, there is also superadded to this already undue velocity, the expulsive power of the radial stream, adding additional velocity to the comet, the orbit is therefore enlarged, and the periodic time increased. Hence the necessity of changing the 'Constant of Resistance' after perihelion, and this will generally be found necessary in all cometary orbits, if this theory be true. But this question is one which may emphatically be

called the most difficult of dynamical problems, and it may be long before it is fully understood."

"No comet that has revisited the sun, has given astronomers more trouble than the great comet of 1843. Various orbits have been tried, elliptical, parabolic and hyperbolic; yet none will accord with all the observations. The day before this comet was seen in Europe and the United States, it was seen close to the body of the sun at Conception, in South America; yet this observation, combined with those following, would give an orbital velocity due to a very moderate mean distance. Subsequent observations best accorded with a hyperbolic orbit; and it was in view of this anomaly, that the late Sears C. Walker considered that the comet came into collision with the sun in an elliptical orbit, and its *debris* passed off again in a hyperbola. That a concussion would not add to its velocity is certain, and the departure in a hyperbolic orbit would be contrary to the law of gravitation. This principle is thus stated by Newton:—'In parabola velocitas ubique equalis est velocitati corporis revolventis in circulo ad dimidiam distantiam; in ellipsi minor est in hyperbola major.' (Vid. Prin. Lib. I., Prop. 6., Cor. 7.)

"But as regards the *fact*, it is probable that Mr. Walker's views are correct so far as the change from an ellipse to a hyperbola is considered. The Conception observation cannot be summarily set aside, and Professor Pierce acknowledges, that 'if it was made with anything of the accuracy which might be expected from Captain Ray, it exhibits a decided anomaly in the nature of the forces to which the comet was subjected during its perihelion passage.' The comet came up to the sun almost in a straight line against the full force of the radial stream; its velocity must therefore necessarily have been diminished. After its perihelion, its path was directly *from* the sun, and an undue velocity would be kept up by the auxiliary force impressed upon it by the same radial stream; and hence, the later observations give orbits much larger than the early ones, and there can be no chance of identifying this comet with any of its former appearances, even should its orbit be elliptical. This unexpected confirmation of the theory by the observation of Captain Ray, cannot be easily surmounted."

"We must now endeavor to explain the physical peculiarities of comets, in accordance with the principles laid down. The most prominent phenomenon of this class is the change of diameter of the visible nebulosity. It is a most singular circumstance, but well established as a fact, that a comet contracts in its dimensions on approaching the sun, and expands on leaving it. In 1829, accurate measures were taken on different days, of the diameter of Encke's comet, and again in 1838. The comet of 1618 was also observed by Kepler with this very object, and also the comet of 1807; but without multiplying instances, it may be asserted that it is one of those facts in cometary phenomena, to which there are no exceptions. According to all analogy, the very reverse of this ought to obtain. If a comet is chiefly vaporous (as this change of volume would seem to indi-

cate), its approach to the sun oughtto be attended by a corresponding expansion by increase of temperature. When the contrary is observed, and invariably so, it ought to be regarded as an index of the existence of other forces besides gravitation, increasing rapidly in the neighborhood of the sun; for the disturbing power of the sun's attraction would be to enlarge the diameter of a comet in proportion to its proximity. Now, the force of the radial stream, as we have shown, is as the 2.5th power of the distances inversely. If this alternate contraction and expansion be due to the action of this force, there ought to be an approximate correspondence of the law of the effect with the law of the cause. Arago, in speaking of the comet of 1829, states, 'that between the 28th of October and the 24th of December, the volume of the comet was reduced as 16,000 to 1, the change of distance in the meantime only varying about 3 to 1.' To account for this, a memoir was published on the subject by M. Valz, in which he supposes an atmosphere around the sun, whose condensation increases rapidly from superincumbent pressure; so that the deeper the comet penetrates into this atmosphere the greater will be the pressure, and the less the volume. In this it is evident, that the ponderous nature of a resisting medium is not yet banished from the schools. In commenting on this memoir, Arago justly observes, that 'there would be no difficulty in this if it could be admitted that the exterior envelope of the nebulosity were not permeable to the ether; but this difficulty seems insurmountable, and merits our sincere regret; for M. Valz's ingenious hypothesis has laid down the law of variation of the bulk of the nebulosity, as well for the short-period comet as for that of 1618, with a truly wonderful exactness.' Now, if we make the calculation, we shall find that the diameter of the nebulosity of a comet is inversely as the force of the radial stream. This force is inversely as the 2.5th power of the distances from the axis, and not from the sun: it will, therefore, be in the inverse ratio of the cosine of the comet's heliocentric latitude to radius, and to this ratio the comet's distance ought to be reduced. But this will only be correct for the same plane or for equal distances above the ecliptic plane, considering this last as approximately the central plane of the vortex. From the principles already advanced, the radial stream is far more powerful on the central plane than in more remote planes; therefore, if a comet, by increase of latitude, approaches near the axis, thus receiving a larger amount of force from the radial stream in that plane than pertains to its actual distance from the sun, it will also receive a less amount of force in that plane than it would in the central plane at the same distance from the axis."

"Admitting the *nucleus* of a comet to be gaseous, there is no difficulty about the solution. According to Sir John Herschel, 'Stars of the smallest magnitude remain distinctly visible, though covered by what appears the densest portion of their substances; and since it is an observed fact, that the large comets which have presented the appearance of a nucleus, have yet exhibited no phases, though we cannot doubt that they shine by the reflected solar light, it follows that even these can only

be regarded as great masses of thin vapor.' That comets shine solely by reflected solar light, is a position that we shall presently question; but that they are masses of vapor is too evident to dispute. According to the same authority quoted above, 'If the earth were reduced to the one thousandth part of its actual mass, its coercive power over the atmosphere would be diminished in the same proportion, and in consequence the latter would expand to a thousand times its actual *bulk*.' If this were so, and comets composed of the elementary gases, some of them would have very respectable masses, as the nuclei are frequently not more than 5,000 miles in diameter, and consequently it becomes important to examine the principle. From all experiment the density of an elastic fluid is directly as the compressing force; and if a cylinder reached to the top of our atmosphere, compressed by the gravitation of the earth, considered equal at each end of the cylinder, it would represent the actual compressing force to which it owes its density. If the gravitation of the earth were diminished one thousand times this atmospheric column would expand one thousand times (taking no account of the decrease of gravitation by the increase of distance);* so that the diameter of the aerial globe would be increased to 108,000 miles, taking the atmosphere at 50 miles. But the mere increasing the *bulk* of the atmosphere 1,000 times would increase the diameter to little more than double. Even giving the correct expansion, a comet's mass must be much greater than is generally supposed, or the diameters of the nuclei would be greater if composed of any gas lighter than atmospheric air."

"It is very improbable that a comet is composed of only one elementary gas, and if of many, their specific gravities will vary; the lighter, of course, occupying the exterior layers. With such a small mass, therefore, the upper portion of its atmosphere must be very attenuated. Now let us remember that the density of the ether at a comet's aphelion, is greater than at the perihelion, in the direct ratio of the square roots of the distances from the sun nearly. At the aphelion the comet lingers through half his period, giving ample time for the nucleus to be permeated by ether proportionally dense with the surrounding ether of the vortex at that distance. Thus situated, the comet descends to its perihelion, getting faster and faster into a medium far less dense, and there must consequently be an escape from the nucleus, or, in common parlance, the comet is positively electric. This escaping ether, in passing through the attenuated layers composing the surface of the nucleus, impels the lighter atoms of cometic dust further from the centre, and as far as this *doubly*

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* In pneumatics, as in hydrostatics, it is the vertical pressure and not extent of surface which counts. The bulk of the earth is to the bulk of earth and atmosphere as $8{,}000^3$ to $8{,}100^3$; and the bulk of the atmosphere is as $\sqrt[3]{8{,}100^3 - 8{,}000^3}$, or in diameter as 2,500 to 8,000, or as 1 to 3.2.

attenuated atmosphere of isolated particles extends, so far will the escaping ether be rendered luminous. It may be objected here, that a contrary effect ought to be produced when the comet is forsaking its perihelion; but the objection is premature, as the heat received from the sun will have the same effect in increasing the elasticity, as change of density, and the comet will probably part with its internal ether as long as it is visible to the earth, and not fully regain it perhaps until after it arrives at its aphelion. Suppose that we admit that a comet continues to expand in the same ratio for all distances, as is laid down for the comet of Encke when near its perihelion, it would follow that the comet of 1811 would have a diameter at its aphelion of 50 millions of millions of miles; that is, its outside would extend 1,000 times further from the sun, at the opposite side to that occupied by the centre of the comet, than the distance of the comet's centre from the sun, at its enormous aphelion distance. Such an absurdity shows us that there is a limit of expansion due to natural causes, and that if there were no radial stream the volume of the comet would be greatest when nearest the sun."

"But while the comet is shortening its distance, and hastening to the sun in the form of a huge globular mass of diffuse light, it is continually encountering another force, increasing in a far more rapid ratio than the law of gravitation. At great distances from the sun, the force of the radial stream was insufficient to detach any portion of the comet's atmosphere; presently, however, the globular form is changed to an ellipsoid, the radial stream begins to strip the comet of that doubly attenuated atmosphere of which we have spoken, and the diameter of the comet is diminished, merely because the luminosity of the escaping ether is terminated at the limit of that atmosphere. Meanwhile the mass of the comet has suffered only an infinitely small diminution; but if the perihelion distance be small, the force may become powerful enough to detach the heavier particles of the nucleus, and thus a comet may suffer in mass by this denuding process. We regard, therefore, the nucleus of a comet to represent the mass of the comet and the coma, as auroral rays passing through a very attenuated envelope of detached particles. We have now to consider the luminous appendage of a comet, commonly called a tail."

"The various theories hitherto proposed to account for this appendage are liable to grave objections. That it is not refracted light needs not a word of comment. Newton supposed the tail to partake of the nature of vapor rising from the comet towards opposition by its extreme levity, as smoke in a chimney, and rendered visible by the reflected light of the sun. But, how vapor should rise towards opposition in a vacuum, is utterly inexplicable. In speaking of the greater number of comets near the sun than on the opposite side, he observes: 'Hinc etiam manifestum est quod cœli resistentiâ destituuntur.'* And again, in another place, speaking of the tail moving with the same velocity of the comet, he says:

* Prin. Lib. Ter. Prop. xxxix.; also Prop. xli.

'Et hinc rursus colligitur spatia cœlestia vi resistendi destitui; utpote in quibus non solum solida planetarum et cometarum corpora, sed etiam rarissimi caudarum vapores motus suos velocissimos liberrimè peragunt ac diutissimè conservant.' On what *principle*, therefore, Newton relied to cause the vapors to ascend does not appear. Hydrogen rises in our atmosphere because specifically lighter. If there were no atmosphere hydrogen would not rise, but merely expand on all sides. But, a comet's tail shoots off into space in a straight line of one hundred millions of miles, and frequently as much as ten millions of miles in a single day, as in the case of the comet of 1843. Sir John Herschel observes, that 'no rational or even plausible account has yet been rendered of those immensely luminous appendages which they bear about with them and which are known as their tails.' Yet, he believes, and astronomers generally believe, that a comet shines by reflected light. This theory of reflection is the incubus which clogs the question with such formidable difficulties; for, it follows, that the reflecting matter must come from the comet. But what wonderful elements must a comet be made of to project themselves into space with such immense velocity and in such enormous quantities as to exceed in volume the body from which they emanate many millions of times! This theory may be, therefore, safely rejected."

"From what we have already advanced concerning the coma or nebulosity of the comet, we pass by an easy path to an explanation of the tail. In the short-period comets, the density of the elementary atoms is too great to be detached in the gross from the nucleus, or rather, the density of the atoms composing the nucleus is too great to permit the radiating stream of the comet carrying them to a sufficient distance to be detached by the radial stream of the sun. Hence, these comets exhibit but very little tails. We may also conceive, that the continual siftings which the nucleus undergoes at each successive perihelion passage, have left but little of those lighter elements in comets whose mean distances are so small. Yet, again, if by any chance the eccentricity is increased, there are two causes—the density of the ether, and the heat of the sun—which may make a comet assume quite an imposing appearance when apparently reduced to the comparatively passive state above mentioned."

"According to our theory, then, the coma of a comet is due to the elasticity of the ethereal medium within the nucleus, caused both by the diminished pressure of the external ether near the sun, and also by the increased temperature acting on the nucleus and thus on the involved ether. The tail, on the contrary, is caused by the lighter particles of the comet's attenuated atmosphere being blown off by the electric blast of the radial stream of the solar vortex, in sufficient quantities to render its passage visible. It is not, therefore, reflected light, but an ethereal stream rendered luminous by this detached matter still held in check by the gravitating force of the sun, whose centre each particle still respects, and en-

deavors to describe such an orbit as results from its own atomic density, and the resultant action of both the acting forces. From the law of density of the ether, the coma ought to be the brightest and the radiating stream of the comet's nucleus strongest on the side of least pressure: from this cause, and the fact that the body of the comet affords a certain protection to the particles immediately behind it, there will be an interval between the comet and the tail less luminous, as is almost invariably observed. We have thus an explanation of the fact noticed by Sir John Herschel, 'that the structure of a comet, as seen in section in the direction of its length, must be that of a hollow envelope of a parabolic form, enclosing near its vertex the nucleus or head.' "We have, also, a satisfactory explanation of the rapid formation of the tail; of its being wider and fainter at its extremity; of its occasional curvature; and of its greater length after perihelion than before. But, more especially may we point to the explanation which this theory gives of the fact, that, *ceteris paribus*, the long-period comets, when their perihelion distances are small, have tails of such exaggerated dimensions." *

"A comet whose mean distance is considerable, is supposed by the theory, to be composed of elements less dense, and during its long sojourn at its aphelion, it may be also supposed that it there receives continual accessions to its volume from the diffused siftings of the system, and from the scattered débris of other comets. On approaching the perihelion, the rapidity of the change in the density of the ether in a given time, depends on the eccentricity of the orbit, and so does the change of temperature; so that, from both causes, both the length of the tail and the brilliancy of the comet measurably depend on the magnitude of the period and the eccentricity."

"If the nuclei of comets be gaseous, as we suppose, and that the smallest stars are visible through them, it is an outrage on common sense to refer that light, which renders a comet visible at noonday, within six minutes of space of the sun itself, to the reflected light of the sun. When a small star has been seen through the nucleus of a comet, without any perceptible diminution of light, it indicates perfect transparency; but there can be no reflection from a perfectly transparent body, and therefore, a comet does not shine by reflected light. It is true that Arago discovered traces of polarized light in the comet of 1819, and also in more recent comets, but they are mere traces, and Arago himself admits, that they do not permit 'the conclusion decidedly that these stars shine only with a borrowed light:' But it still does not follow that a comet (even if independent of reflected light) is in an incandescent state. The auroral light is not polarized, nor any other electric light, neither is it owing to a state of incandescence, yet it is luminous. The

* This is now more fully explained by that important consequence of the theory, viz., the central condensation—the fruit of a more thorough investigation (1883).

intense light of a comet at perihelion is analogous to the charcoal points of a galvanic battery, caused by a rapid current of ether from the nucleus, and assisted by the radial stream of the vortex. This will account for the phenomenon in all its shades of intensity, as well as for the absence of any perceptible phase. It will also account for the non-combustion of such comets as those of the years 1680 and 1843. We shall also be at no loss to understand, why there is no refraction when a ray of light from a star passes through the nebulosity of a comet; and if, as we may reasonably suppose, the gaseous matter composing the nucleus be very attenuated, instruments are yet too imperfect to determine whether these also have any refracting power. On this point, however, it is safest to suspend our judgment, as there may be comets not belonging to our system, with even liquid or solid nuclei, or of matter widely different to those elements composing the members of the solar system."

"In addition to what has been already advanced on this subject of a comet's light, we may appeal to the well-known fact that the visibility of a comet is not reciprocally as the squares of the distances from the earth and sun as it ought to be, if shining by reflected light. In Mr. Hind's late work on comets, the fact is stated that 'Dr. Olbers found that the comet of 1780 attained its greatest brightness on the 8th of November, thirteen days subsequent to its discovery; whereas, according to the law of reflected light, it should have become gradually fainter from the day of its discovery; and supposing the comet self-luminous, the intensity of light should have increased each day until November 26th; yet in the interval between the 8th and 26th of that month, it grew rapidly less.' Now this theory teaches, that a comet is neither self-luminous nor dependent on the sun, but on its distance from the axis of the vortex, and a certain amount of elapsed time from the perihelion, varying somewhat in each particular case. This fact is therefore a very strong argument in favor of our theory."

"In speaking of the modifying causes which influence the weather, we mentioned the effect due to the position of the sun with respect to the axis of the vortex. This will be found to have a sensible effect on the action of the radial stream. The natural direction of a comet's electric stream is *toward* the axis of the vortex, and in the central plane it will be also toward the sun. But this stream is met by the stronger radial stream from the axis, and as Mr. Hind describes it, 'is driven *backward* in two streams passing on either side of the head, and ultimately blending into one to form the tail.' Now, if the body of the sun be situated between the comet and the axis of the vortex, it will shield the comet from the action of the radial stream, and thus a tail may really point toward the sun."

"In 1744, a brilliant comet exhibited six distinct tails spread out like a fan, some seven days after its perihelion passage; its distance from the sun at the time not being more than a third of the earth's distance. The comet was then rapidly approaching the plane of the ecliptic, and if we

make the calculation for the position of the sun, we shall find that the body of the sun was on the same side of the axis of the vortex as the comet, and that the comet was then situated at the boundaries of the conical space, enclosed by the radial stream in its deflected passage round the body of the sun. In this position there are numerous cross currents of the stream, and hence the phenomenon in question. As this fact rests on the testimony of one individual, and is an occurrence never recorded before or since, many are disposed to doubt the fact, yet our theory explains even this peculiarity, and shows that there is no necessity for impugning the statement of Cheseaux."

"Another unexplained phenomenon is the corruscation of the tail. It has been attempted to explode this fact also, by referring it to conditions of our own atmosphere; and it is generally considered the argument of Olbers, founded on the great length of the tail and the velocity of light, is sufficient to prove that these corruscations are not actually in the tail. Now, it is undoubtedly true, that as light travels less than two hundred thousand miles in a second, and a comet's tail is frequently one hundred millions of miles long, it is impossible to see an instantaneous motion along the whole line of the tail; but, granting that there are such flickerings in the tail as are described by so many, it must necessarily be, that these flickerings will be *visible*. It would be wonderful indeed, if a series of waves passing from the comet to the extremity of the tail, should have their phases so exactly harmonizing with their respective distances as to produce a uniform steady light from a light in rapid motion. The argument, therefore, proves too much, and as it is in the very nature of electric light thus to corruscate, as we see frequently in the northern lights, we must be permitted still to believe that not only the tails, but also the heads of comets do really corruscate as described."

"With respect to the direction of the tail, astronomers have been forced to abandon the antiquated notion, that the tail always pointed directly from the sun; yet they still pertinaciously cling to the idea, that although this is not always the case, the tail only deviates from this direction *in the plane of the orbit*. As this is a most important question, it is necessary formally to protest against such a conclusion. If the earth should happen to be in the plane of the comet's orbit and the tail appears in that plane, it must of course be in that plane *really;* but if the earth is not in the plane of the comet's orbit, the tail is not *necessarily* in the same plane, whatever its apparent direction may indicate. It is true, there is a tendency of every particle of the tail, moving under the restraining influence of the sun's attraction, to continue in the plane of the orbit; and in certain positions there is no oblique action arising from the force of the radial stream to cause it to deviate from that plane; yet in other positions of the comet, the action of the radial stream may be oblique, forcing it out of that plane, and still such a direction might be assigned to it as to make it conform. In the comet of 1843, P. Smythe observed a forked tail 25° long on March 3d, and from the end of the forked tail, and from

its *north* side a streamer diverged at an angle of 6° or 7° to the *north*. As this was contrary to the *direction* of the curvature, if the tail had been curved, it could only arise from a portion being driven off by the radial stream, or bent toward the plane of the ecliptic. The curvature observed by others at a later date, was concave to the south. Toward the middle and close of March, the tail became straight, and, with the above exception, might be considered to move in the plane of the orbit."

"The celebrated comet of Halley, as observed by Dr. Bessel in 1835, showed that a more or less well-defined tuft of rays emanated from that part of the nucleus which was turned toward the sun; and the rays being *bent backward* formed a part of the tail. The nucleus, with its emanations, presented the appearance of a burning rocket, the end of which was turned sideways by the force of the wind. And, Bessel concludes: 'That the cone of light issuing from the comet deviated considerably both to the right and left of the true direction of the sun, but that it always returned to that direction, and passed over to the opposite side; so that the cone of light, and the body of the comet from whence it emanated, experienced a rotatory, or, rather, a vibrating motion *in the plane of the orbit*.' It is impossible that Bessel should here mean that this motion was certainly in the plane of the orbit; for the orbit was then viewed sideways, and he had no means of ascertaining the fact. His meaning must be that it was apparently in the plane of the orbit. If a plane be made to pass through the earth, the comet, and the sun, the tail might be placed in any position in that plane, and yet appear to be at the intersection; that is, in the plane of the comet's orbit. The vibration of the tail, in this case, is another strong proof of the correctness of our theory."

"Prof. Struve compared the tail of this comet to a flame, or 'ray of fire shot out from the nucleus, as from some engine of artillery, and driven on one side by the wind. At the same time, he saw a second emanation nearly in the opposite direction. This last might arise from a momentary fluctuation in the relative intensities of the electric radiation of the comet, and of the radial stream, owing to the probable irregularities just alluded to. Such, and kindred phenomena are utterly inexplicable, without we adopt the theory we are advocating. One other feature and we will leave the subject."

"From our explanation of the solar spots, we inferred the existence of another large planet in the system. Might not the same effect be produced by a comet? Or may there not be so many comets, whose great elongation, combined with even a moderate mass, may render it impossible to calculate the position of the sun with respect to the central axis of the vortex—always considering this last as the axis of equilibrium? In a general way, we might say that the very number of comets in all directions and all distances, would tend to neutralize each other's effects; but we are not under this necessity. A comet, moving in a parabola, does not belong to the system or to the rotating vortex; and the periodic comets, if of gaseous elements (as seems so probable), must, from the size of their

nuclei, which the theory considers the only part constituting their mass, have far less mass than the very smallest of the asteroids, and consequently could have very little effect on the mechanical balance of the vortex, even if elongated as far as the orbit of Neptune. Did we know the influence of cold in limiting the expansibility of the elementary gases, we might approximately determine the mass of a comet, from the size of its nucleus; but this is a problem that has never yet been solved; and astronomers ought to avail themselves of every indication which promises to realize this great desideratum."

(See "Mechanical Theory of Storms," page 187.)

The theory of cometary phenomena as presented in the preceding pages is not contradicted by the author's later investigations in any essential particular. But more matured views of the nature and motions of the ethereal medium have improved it, by rendering it more capable of reconciling the conflicting testimony which almost every comet brings with it —a fact which has hitherto clothed all cometary phenomena with such an impenetrable veil of mystery.

NOTE I.

THE return of another periodical comet, discovered by Pons in 1812, has been announced since the manuscript of this volume was delivered to the publishers. This is the more interesting, as being the return of the first comet of long period determined solely by calculation, and not on any suspected previous apparition. It appears now (Oct. 27th) as a circular nebulosity with condensed centre, tolerably bright in a good telescope, but sure to be overlooked in a poor one. From present indications it will scarcely be visible to the naked eye much before the middle of December.

In the "North American Review" for November, 1883, Prof. Balfour Stewart gives 1877 as the minimum sun spot year, agreeing with our Table III., and rejecting Doctor Wolf's date, 1879. He also agrees in giving 1828 as a maximum year, instead of Wolf's date, 1830. He also inclines to the evidence of maximum years being favorable to the more frequent occurrence of cyclones and hurricanes at such times, while his views confirm our positions as respects the sun's rays being least powerful at the epochs of maxima and the temperature the lowest; but the demurrer which he offers on behalf of others, that "if the rain-fall be greatest at times of maximum sun spots, it would seem to follow that the temperature might then be the lowest," is a questionable supposition. There are, no doubt, great rain-falls during a season of maximum, for cyclones are generally so accompanied; but the annual rain-fall at such times is very unequally distributed, and the times of minimum sun spots are far more strongly marked with seasonable rains, generally distributed.

On a previous page (146) we remarked that in 1822 the centre of the

sun and the centre of gravity of the system came nearer to coincidence than in any year of the century, but it was then unknown to the author whether the season was similar to that of 1811, another minimum year famous for its harvests and comet wine. Since that was written, the author has found it recorded that it was a remarkably warm and fruitful year, and so was the following minimum in 1833; while 1816, a maximum year, was the very opposite in every particular. A maximum sun spot year is no blessing to our world, as Ischia and Java can testify for 1883. But Prof. Stewart has unconsciously given our theory the sanction of his name, as appears in the proceedings of the British Association for the Advancement of Science. From thirty-six years of observation, Prof. Stewart, aided by Mr. W. L. Carpenter, derived a short period sun spot inequality of twenty-six days. On page 153 we have given Prof. Tacchini's report as it appears in the "Comptes Rendus," Vol. XCIII., No. 8, which shows that the average semi-rotation is exactly 13 days, corresponding to Prof. Stewart's 26 day period. (See page 166.) If it be objected that the equatorial synodical period is 27 days, we may say that 26 days is the sidereal rotation of the 24th parallel of solar latitude, according to our formula on page 83; for

$$\frac{360^\circ}{872' - 100' \text{ Sine } 24^\circ} = 26 \text{ days.}$$

But extreme accuracy cannot be relied on in such observations. Yet there is nothing improbable that latitude 24° may be the central line of the maximum spot latitude. The *exact* period is, however, of little consequence, as the approximate period shows, unmistakably, the important influence which the sun's sidereal rotation exerts in the short period spot inequalities, which presents the same portions of the surface to the axis of the vortex about every 26 days, or if we allow for the average *revolution* of the sun, we get 26½ days for the axial rotation.

The rosy sunsets which were so conspicuous about the first of the month (December) have excited attention even in Europe, and speculation has been rife concerning the cause. Now in 1783 a similar phenomenon was observed and called a dry fog, and the same year Mount Hecla, in Iceland, convulsed the island more terribly than previous or subsequent history has recorded. In the same year Calabria, in Sicily, was overthrown, entombing forty or fifty thousand people beneath its ruins. That year was a year of maximum sun spots, according to our Table III., differing, it is true, from Doctor Wolf's maximum—the only *real* difference between us—a difference, however, easily accounted for. This year also is a year of maximum sun spots, and we have a similar dry fog, while the activity of the earthquake will mark 1883 as the great earthquake year of the century.

These coincidences ought to bespeak some little toleration for a theory which links them to an intelligible mechanical cause.

On page 138 we have given the elements of our hypothetical planet—

the results of much weary thought and labor. The most probable mean distance has been found to be 47, taking the earth's mean distance as the unit. Now it will no doubt occur to many, that such distance is not in conformity with Bode's empirical law ; and therefore may be considered an argument against our figures ; but neither does the planet Neptune conform to that law, as the following comparison with Bode's numbers will show. These numbers being derived by adding 3.0 to Mercury's distance (taken as 4.0) for Venus ; then again adding 4.0 to 2 × 3.0 for the earth and continuing to add 4.0 to each succeeding term of the series 4 × 3.0, 8 × 3.0, etc., for the rest of the planets.

COMPARISON OF BODE'S LAW OF THE PLANETARY DISTANCES WITH ACTUAL DISTANCES.

Distances.	Mercury.	Venus.	Earth.	Mars.	Asteroids.	Jupiter.	Saturn.	Uranus.	Neptune.
In geometrical ratio.....	0.0	3.0	6.0	12.0	24.0	48.0	96.0	192.0	384.0
Mercury's distance.....	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
According to Bode	4.0	7.0	10.0	16.0	28.0	52.0	100.0	196.0	388.0
Actual.....	3.9	7.2	10.0	15.2	28.0	52.0	95.4	191.8	300.6

Here we see a great discrepancy in the case of Neptune ; but if we take the mean (as in the case of the asteroids) of Neptune and planet VIII., we get $\frac{300.6 + 470.0}{2} = 385.3$, which corresponds better with Bode's law than in the case of several of the other planets.

Now if it should turn out that the dynamical influence of our planet VIII. is really due to two planets, the consistent testimony of all the planets inside the orbit of Neptune to the approximate accuracy of Bode's law would (at the outset) impose the condition that the average distance of those two undiscovered planets, conjoined with Neptune, should roughly conform to the series indicated in the above table. The corresponding term of the series for Neptune is..... 388.80

but Neptune's distance is only..... 300.06
and planet VIII. is computed to be..... 470.00 } ÷ 2 = 388.53

Diff. = .27

Now if there be two planets in nearly the same longitude, their respective distances will probably (although not necessarily) be inversely as their masses, and the sum of those products equal to the product of the mass of our hypothetical planet by its distance. But if the distances differed materially the periodic times would also differ materially, and there could not be that correspondence between theory and observation which our planetary curve shows when compared with the solar spot curve for 100

years. (Fig. 24.) We therefore infer that, if there be two planets instead of one, their mean distances do not vary much; although the obstacles to their discovery would be thereby seriously exaggerated. The fact is well known that Neptune will not account for the whole of the residuary errors of Uranus, and Neptune itself has very large residuals; it is therefore almost certain that another planet exists outside of Neptune, and any theory which affords a clue to its location, is surely worthy of consideration in such an important question, and it is here respectfully hinted that the retrograde character of our planet VIII. may throw some light on Wartman's planet of 1831 (four places of which were given in the "Comptes Rendus" for 1836), provided that there are two planets instead of one, the average of whose distances is approximately, forty-seven times the earth's mean distance. As yet there has been no satisfactory explanation given of Bode's law, although it is no doubt due to the law of density of the ethereal medium and the law of the radial stream in the solar vortex, which, conjointly, determine the order of each planet according to its density and diameter; yet its approximate verification within the orbit of Neptune invests it with the halo of truth, and this idea of an average distance for all trans-Uranian planets fulfilling the requirements of that law greatly confirms our value of the distance of the hypothetical planet of the theory. But this idea came too late to lighten the labor of obtaining it.

On page xxxvii. of the Introduction will be found the Table of Elements of the seven electrical vortices as it appeared in a paper read before the Physical Section of the A. A. A. S., convened at Cincinnati in August, 1881. In that table certain slowly variable elements were assumed as constant, viz.:

C = Inclinat'n of the terra-lunar vortex to the earth's equator = 22°.22′

☊ = Ascending node of " on " = 184°.20′ *

Now although the weather part of the theory is secondary to the solar phenomena discussed in this volume, yet it may be useful to remove from the readers' path all obstacles tending to mislead him by bringing up the elements of the theory to the present time.

As the nodes of the lunar orbit recede on the ecliptic, it is found also that the nodes of the vortex recede at the same rate, and are identical in mean longitude with the nodes of the orbit. The nodes of the moon's equator are also found similarly disposed, with this exception, the ascending node of the equator differs from that of the orbit by exactly 180°.

The cause of this remarkable fact has never yet been explained; but it only confirms a general principle that, in every system united by material ties, there will be a constant effort to maintain a mechanical equilibrium, and therefore, where gravitation fails to account for it, the existence of a material medium linking every part of that system to every

* A descending *passage* of a vortex is at this time made nearest the ascending node of the vortex on the ecliptic.

other part, is a conclusion which cannot be ignored. Yet while the lunar orbit is inclined 5° 9′ to the ecliptic, the moon's equator is only inclined 1° 30′ to the ecliptic, while the inclination of the vortex plane is intermediate, or about 4°20′, so that, for the year 1885, C may be safely taken = 19° constant, and the nodes in 180° and 360° respectively.

To those who seek to verify the theory by observation, let them remember that the principal and most important fact to be verified is the evidence of a weather disturbing cause soon *after* the computed times of passages, in the latitude and longitude given by the computation. When satisfied that these vortices are a part of the atmospheric machinery of the world, by which the land is watered and the air preserved from stagnation, they can then devote themselves to the interpretation of that evidence.

TABLES.

TABLE I.—Dr. R. Wolf's Monthly Relative Numbers of Sun Spots Visible from 1749 to 1876.

YEAR.	FIRST MONTH.	SECOND MONTH.	THIRD MONTH.	FOURTH MONTH.	FIFTH MONTH.	SIXTH MONTH.	SEVENTH MONTH.	EIGHTH MONTH.	NINTH MONTH.	TENTH MONTH.	ELEVENTH MONTH.	TWELFTH MONTH.	MEAN.
1749	——	——	——	——	——	——	81.6	82.8	84.1	86.3	87.8	88.7	——
1750	89.0	90.2	92.3	92.6	88.2	83.8	83.3	81.8	78.6	75.4	72.9	69.6	83.1
1751	66.8	64.2	59.5	54.6	51.7	48.8	46.2	45.0	46.3	47.5	47.6	47.1	52.1
1752	47.2	46.4	45.3	46.4	47.8	48.0	48.2	47.8	46.0	44.1	42.1	40.9	45.9
1753	38.2	36.2	36.7	35.8	35.0	32.1	28.8	25.8	22.8	19.9	18.3	17.4	28.9
1754	17.1	15.8	13.9	13.0	12.7	12.3	12.6	13.4	14.0	13.9	12.7	10.7	13.5
1755	9.2	8.4	8.4	8.8	8.5	8.9	9.7	9.6	9.4	9.4	10.0	11.1	9.3
1756	11.4	11.4	11.3	10.6	10.6	10.6	10.3	10.9	12.4	14.1	16.0	17.1	12.2
1757	18.0	20.7	23.8	25.7	28.4	31.4	33.4	35.7	37.9	40.6	42.7	44.4	31.9
1758	46.5	46.8	47.2	48.4	47.7	47.2	48.0	48.2	47.7	46.5	45.6	46.0	47.1
1759	46.5	48.1	50.1	51.6	52.7	53.4	54.8	56.2	58.0	60.5	61.9	61.9	54.6
1760	62.5	63.3	62.8	61.8	62.0	62.7	63.0	64.4	66.0	66.8	68.8	72.4	64.7
1761	75.7	77.5	79.8	83.0	85.8	86.5	84.8	82.9	80.7	78.8	75.5	71.7	80.2
1762	68.3	64.8	62.5	60.4	59.0	59.8	61.7	60.5	58.3	56.7	55.3	53.2	60.0
1763	52.4	51.5	49.8	48.8	47.1	45.8	45.3	46.5	47.9	48.3	48.8	49.0	48.4
1764	47.8	46.9	45.4	43.0	40.8	37.8	34.9	32.0	29.9	28.8	27.3	25.8	36.7
1765	25.3	25.2	24.6	23.6	22.5	21.4	20.4	19.3	19.1	19.0	18.6	18.1	21.4
1766	16.4	14.4	12.7	12.0	11.2	11.1	12.0	13.5	14.5	15.9	17.2	18.6	14.1
1767	20.6	22.9	26.0	29.3	32.9	36.4	38.9	41.5	43.1	43.7	46.1	49.9	35.9
1768	53.0	55.4	57.8	60.6	63.5	67.4	70.7	71.5	72.1	75.1	77.2	77.7	66.8
1769	81.2	86.2	91.5	98.1	103.8	106.1	107.3	111.9	115.8	114.6	112.5	111.9	103.4
1770	111.1	110.9	109.3	105.2	102.3	101.2	98.0	91.1	85.7	84.9	88.9	93.9	98.5
1771	93.6	89.0	86.1	85.4	83.5	81.9	84.3	88.8	90.1	90.5	86.9	79.5	86.6
1772	77.3	77.6	75.4	72.8	70.7	67.8	64.6	60.1	58.3	56.7	54.3	53.3	65.7
1773	50.0	46.1	43.5	40.4	37.4	35.6	34.5	35.6	37.3	38.0	38.9	39.3	39.7
1774	38.8	38.2	37.1	35.6	34.2	31.9	28.9	24.4	19.8	16.6	13.2	10.6	27.4
1775	9.3	8.6	8.5	7.9	7.5	7.2	7.7	8.9	9.2	9.4	10.2	10.7	8.8

1776	11.0	11.7	12.9	14.5	16.3	18.5	20.8	23.8	25.2	29.6	35.6	41.0	21.7
1777	45.9	55.1	62.9	70.3	78.1	87.5	98.0	106.6	113.5	119.6	128.2	138.6	92.0
1778	144.8	148.4	151.9	156.3	158 5	156.5	156.0	151.5	153.2	152.5	148.4	141.9	151.7
1779	139.0	137.5	133.8	129.9	127.0	125.7	124.1	119.4	115.7	112.8	109.3	106.9	123.4
1780	103.5	100.0	98.2	95.5	91.3	86.9	86.0	86.2	83.4	80.4	79.2	79.5	89.2
1781	79.4	78.0	75.4	71.5	69.8	69.1	66.2	62.8	60.6	58.8	55.6	51.0	66.5
1782	47.0	44.5	42.9	42.0	40.4	38.7	37.4	36.3	36.0	35.0	33.2	31.4	38.7
1783	30.6	29.4	27.7	26.4	25.1	23.6	22.2	20.3	18.3	17.0	15.5	14.1	22.5
1784	12.3	10.8	10.0	9.7	9.8	10.0	9.9	9.6	9.5	9.7	10.5	11.9	10.3
1785	13.9	15.5	16.9	19.4	22.0	23.5	25.4	28.3	31.6	36.1	42.0	46.8	26.7
1786	49.6	54.5	60.7	66.7	72.6	79.3	86.9	93.4	97.5	100.9	104.4	107.9	81.2
1787	111.4	115.3	119.2	122.9	125.8	129.5	132.2	133.3	136.6	138.1	136.4	137.8	128.2
1788	140.6	141.2	140.4	139.1	136.6	132.8	129.9	128.7	127.6	127.3	128.3	127.3	133.3
1789	124.9	122.5	119.1	116.5	116.0	117.9	117.6	117.3	116.4	114.2	111.7	109.2	116.9
1790	106.0	103.4	101.2	99.6	97.1	92.4	88.6	84.6	80.9	79.3	77.8	75.9	90.6
1791	74.8	73.1	70.8	69.4	67.8	66.9	65.9	65.4	65.0	64.5	63.9	63.3	67.6
1792	62.1	61.8	62.2	61.8	62.1	61.2	59.9	59.5	58.8	57.5	56.2	55.3	59.9
1793	55.1	54.0	51.3	49.3	48.3	47.3	46.4	45.5	44.3	42.6	41.7	41.4	47.3
1794	40.7	40.7	40.7	39.1	38.9	40.1	39.4	38.2	37.0	35.5	34.1	32.0	38.0
1795	29.8	28.1	27.6	27.6	25.8	22.7	21.3	20.6	20.1	20.8	20.9	20.1	23.8
1796	20.2	19.8	19.0	18.9	17.8	16.6	15.7	14.6	13.3	11.6	9.9	9.5	15.6
1797	8.8	8.0	7.7	7.0	6.7	6.5	5.9	5.4	5.7	5.9	5.5	4.7	6.5
1798	4.1	3.8	3.5	3.2	3.3	3.8	4.0	4.4	5.1	5.8	6.5	7.3	4.6
1799	7.8	7.8	7.5	7.5	7.3	6.8	7.0	7 1	6.6	6.4	6.8	7.1	7.1
1800	8.0	9.6	10.9	11.7	12.4	14.0	16.2	17.8	19.3	20.8	22.8	24.3	15.6
1801	25.2	26.6	28.3	30.0	32.1	33.7	34.9	36.5	37.7	38.9	40.6	42.5	33.9
1802	44.4	46.1	48.2	50.5	52.6	54.3	55.7	57.3	59.3	61.2	62.8	64.2	54.7
1803	65.6	66.5	67.2	68.4	69.7	70.7	71.7	72.5	73.2	73.9	74.5	74.9	70.7
1804	75.1	75.5	75.7	75.3	74.7	73.7	72.5	71.1	69.6	67.5	64.6	61.9	71.4
1805	59.6	57.4	55.2	52.9	50.6	48.6	46.7	44.6	42.2	40.5	39.4	37.9	48.0
1806	36.3	34.9	33.6	32.2	30.9	29.6	27.8	25.9	24.4	23.0	21.7	20.3	28.4
1807	18.9	17.5	15.8	14.1	12.4	10.4	8.9	8.1	7.4	6.8	6.4	6.5	11.1
1808	6.3	5.9	5.9	6.1	6.3	7.2	8.0	8.5	8.7	8.3	7.7	7.2	7.2

TABLE I.—Dr. R. Wolf's Monthly Relative Numbers of Sun Spots Visible from 1749 to 1876.—*Continued.*

YEAR.	FIRST MONTH.	SECOND MONTH.	THIRD MONTH.	FOURTH MONTH.	FIFTH MONTH.	SIXTH MONTH.	SEVENTH MONTH.	EIGHTH MONTH.	NINTH MONTH.	TENTH MONTH.	ELEVENTH MONTH.	TWELFTH MONTH.	MEAN.
1809	6.8	6.2	5.4	4.7	4.0	3.0	2.2	1.6	1.1	1.0	0.8	0.4	3.1
1810	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1811	0.0	0.3	0.5	0.6	1.3	1.4	2.0	2.6	2.7	2.7	2.8	2.9	1.6
1812	2.7	3.2	4.1	4.2	4.5	5.1	5.0	4.8	5.1	5.9	6.8	7.3	4.9
1813	8.4	8.6	8.7	10.3	11.7	12.4	13.8	14.8	15.0	15.4	15.7	15.9	12.6
1814	16.2	16.0	15.5	14.9	14.4	14.3	14.3	15.0	16.7	17.9	18.4	20.3	16.2
1815	22.7	25.3	27.9	29.2	30.7	33.5	35.7	37.5	41.0	44.1	46.7	47.6	35.2
1816	47.3	46.6	46.5	48.2	49.2	47.8	46.8	46.7	47.5	47.5	45.1	43.9	46.9
1817	44.1	45.2	45.4	43.5	42.1	41.8	41.5	39.9	34.8	31.7	33.5	34.8	39.9
1818	33.8	32.4	31.4	31.4	30.8	29.9	29.9	30.0	29.3	27.9	25.8	24.3	29.7
1819	24.6	24.6	23.9	23.1	23.3	24.0	23.4	22.7	22.9	22.9	23.8	22.7	23.5
1820	21.2	20.6	20.4	19.2	17.6	15.9	15.4	14.8	13.8	13.4	11.7	10.2	16.3
1821	8.9	7.2	6.3	6.7	6.9	6.4	5.2	4.3	4.6	5.3	5.7	5.8	6.1
1822	6.1	6.3	6.0	5.0	4.1	4.0	4.0	3.9	3.2	2.0	1.5	1.2	3.9
1823	0.6	0.2	0.1	0.1	0.1	0.9	2.7	4.0	4.5	5.3	6.2	6.8	2.6
1824	6.3	6.3	7.2	9.2	10.2	9.4	7.9	7.4	8.2	8.0	7.7	8.9	8.1
1825	10.8	13.1	13.9	13.3	13.4	14.7	16.1	16.8	17.8	19.8	21.5	23.1	16.2
1826	24.9	26.4	27.1	28.7	31.4	34.2	36 9	38.5	40.5	42.1	44.0	45.8	35.0
1827	46.2	46.3	48.2	49.8	50.4	50.1	50.1	51.6	52.8	53.8	55.8	58.9	51.2
1828	61.2	62.5	63.6	62.7	62.0	62.4	62.1	61.1	60.7	62.6	63.2	61.3	62.1
1829	61.9	63.5	63.5	64.6	66.1	66.9	67.6	68.8	70.2	71.1	71.5	70.9	67.2
1830	68.5	65.5	64.9	66.3	67.9	69.7	70.6	69.6	69.1	67.3	63.4	61.4	67.0
1831	60.1	60.4	59.6	57.0	53.8	50.0	47.1	46.6	45.8	42.5	41.5	41.3	50.4
1832	39.8	36.5	33.4	31.1	28.9	27.5	26.7	24.2	20.7	17.9	15.7	13.5	26.3
1833	12.0	11.6	11.6	11.2	10.3	9.2	8.2	8.0	7.9	7.6	7.3	7.4	9.4
1834	7.7	7.7	7.7	8.4	10.2	12.2	13.3	13.7	14.6	17.8	21.7	24.2	13.3
1835	27.4	31.9	37.9	44.5	50.4	55.1	60.2	67.0	73.8	80.5	86.7	93.2	59.0

1836	99.5	108.9	105.7	107.2	109.8	116.0	125.6	133.0	136.9	138.2	138.0	139.4	119.3
1837	142.7	145.7	146.9	146.3	145.2	141.4	136.4	130.9	127.4	127.1	127.7	126.2	136.9
1838	125.4	120.8	118.4	111.2	108.6	105.8	101.6	100.7	98.8	93.5	87.3	82.2	104.1
1839	79.5	80.7	85.4	87.9	87.5	86.5	84.7	83.0	81.5	80.7	81.5	81.9	83.4
1840	80.6	76.5	71.0	66.9	64.6	63.6	60.8	56.0	52.5	50.5	49.5	49.6	61.8
1841	48.7	46.7	44.3	41.8	39.5	37.4	36.8	36.2	35.5	34.5	32.1	28.8	38.5
1842	26.7	25.3	24.1	23.8	25.0	25.0	23.9	23.8	21.5	20.1	19.3	18.8	23.0
1843	18.0	17.3	16.1	14.2	11.9	10.8	10.4	10.7	11 5	12.2	12.3	11.7	13.1
1844	11.9	12.9	13.5	14.2	14.6	14.7	15.7	17.6	20.0	22.7	25.7	28.3	19.3
1845	29.9	30.6	31.9	33.7	34.8	37.7	40.6	41.4	42.7	44.0	45.0	46.9	38.3
1846	49.0	50.6	54.7	58.7	60.1	61.2	62.5	63.2	63.8	63.8	63.4	64.8	59.6
1847	65.9	69.8	75.6	83.0	91.5	96.7	102.5	109.3	113.1	116.6	120.3	123.0	97.4
1848	128.2	131.5	128.6	124.1	121.1	122.2	124.2	124.9	125.2	124.5	123.4	120.7	124.9
1849	116.4	110.9	107.6	104.8	101.7	98.5	92.6	87.6	85.2	83.8	78.8	77.7	95.4
1850	75.6	74.0	73.7	73.4	71.5	68.1	66.4	67.0	66.9	66.7	67.2	67.0	69.8
1851	66.6	66.3	65.3	64.2	63.7	64.0	64.2	62.3	60.6	60.8	60.9	59.7	63.2
1852	59.4	58.9	57.0	55.9	56.2	55.3	53.1	50.9	48.9	47.2	45.6	44.5	52.7
1853	44.4	44.9	45.2	44.0	41.9	40.0	38.0	35.9	34.3	32.7	31.4	30.1	38.5
1854	28.2	25.7	23.7	22.0	20.7	20.6	20.4	20.0	19.4	18.4	16.9	15.5	21.0
1855	14.1	12.8	11.4	10.4	9.2	7.5	6.2	5.5	4.5	3.9	3.5	3.2	7.7
1856	3.3	3.6	3.9	3.9	3.8	4.1	4.8	5.5	5.8	6.2	7.6	9.2	5.1
1857	10.4	11.6	13.7	16.8	19.3	21.5	23.8	26.0	29.3	32.6	34.3	36.0	22.9
1858	38.6	41.7	44.8	48.5	51.4	53.5	56.7	60.7	64.3	67.6	71.7	75.5	56.2
1859	78.9	82.6	85.9	87.9	90.8	93.2	93.7	93.7	94.0	93.8	93.9	95.4	90.3
1860	97.2	97.9	97.0	95.4	94.4	95.1	94.9	93.7	93.3	94.5	93.6	90.6	94.8
1861	88.1	85.8	84.5	83.1	80.3	77.8	77.2	76.7	78.7	69.5	67.9	68.1	77.7
1862	67.7	66.7	65.3	63.7	62 5	60.8	58.5	57.6	58.2	58.6	57.6	55.3	61.0
1863	51.9	49.6	47.1	45.2	44.5	44.0	44.4	44.4	44.0	43.8	43.0	43.2	45.4
1864	44.8	46.0	46.6	46 6	47.2	47.5	46.6	45.9	44.4	43.0	42.5	41.3	45.2
1865	39.1	37.2	36.2	35.2	33.2	31.1	29.8	29.0	28.4	27.2	25.9	24.2	31.4
1866	22.8	21.0	19.4	18.7	17.9	16.8	15.0	12.1	9.9	8.7	7.8	6.8	14.7
1867	5.9	5.4	5.2	5.3	5.3	6.3	7.9	9.2	10.5	12.6	14.9	17.1	8.8
1868	19.3	21.5	24.2	27.6	31.7	35.5	39.2	42.9	45.8	47.0	50.4	56.9	36.8

TABLE I.—Dr. R. Wolf's Monthly Relative Numbers of Sun Spots Visible from 1749 to 1876.—*Continued.*

YEAR.	FIRST MONTH.	SECOND MONTH.	THIRD MONTH.	FOURTH MONTH.	FIFTH MONTH.	SIXTH MONTH.	SEVENTH MONTH.	EIGHTH MONTH.	NINTH MONTH.	TENTH MONTH.	ELEVENTH MONTH.	TWELFTH MONTH.	MEAN.
1869	61.4	64.5	68.0	69.4	70.1	72.4	74.6	77.6	84.3	98.7	101.7	105.8	78.6
1870	110.0	116.2	121.6	127.5	134.0	138.0	139.6	140.5	140.2	139.6	138.5	135.4	131.8
1871	132.3	129.8	125.1	120.4	116.3	112.9	110.8	110.3	107.8	103.0	98.9	98.0	113.8
1872	98.9	98.3	99.0	101.0	101.9	101.9	102.0	101.8	101.6	100.9	97.8	92.1	99.7
1873	87.8	85.2	81.4	75.4	70.7	67.8	65.2	62.3	58.4	54.4	52.4	52.0	67.7
1874	51.8	51.5	50.4	49.1	47.4	45.5	42.7	39.0	36.8	36.1	34.6	32.7	43.1
1875	29.8	25.5	22.5	20.5	19.3	17.9	17.1	16.8	16.3	15.1	13.7	12.5	18.9
1876	11.7	11.6	11.7	12.0	11.8	11.4	——	——	——	——	——	——	——

TABLE II.

YEAR.	RECTANGULAR CO-ORDINATES OF THE FOUR GREAT PLANETS, THE SUN'S CENTRE BEING THE ORIGIN AND ITS RADIUS THE UNIT OF MEASURE. EQUINOX, 1850.								SUM OF THE COMPONENTS OF X AND Y.	
	$M^{iv}\ X^{iv}$	$M^{v}\ X^{v}$	$M^{vi}\ X^{vi}$	$M^{vii}\ X^{vii}$	$M^{iv}\ Y^{iv}$	$M^{v}\ Y^{v}$	$M^{vi}\ Y^{vi}$	$M^{vii}\ Y^{vii}$	X′	Y′
1783	+ 0.2092	+ 0.0506	− 0.0238	− 0.3256	− 1.0405	− 0.6159	+ 0.1911	− 0.0500	− 0.0896	− 1.5153
1784	+ 0.6892	+ 0.1662	− 0.0383	− 0.3235	− 0.7772	− 0.5938	+ 0.1881	− 0.0622	+ 0.4986	− 1.2451
1785	+ 0.9653	+ 0.2755	− 0.0527	− 0.3210	− 0.2613	− 0.5486	+ 0.1838	− 0.0743	+ 0.8671	− 0.7004
1786	+ 0.9624	+ 0.3739	− 0.0666	− 0.3181	+ 0.3229	− 0.4817	+ 0.1787	− 0.0863	+ 0.9516	− 0.0664
1787	+ 0.6349	+ 0.4568	− 0.0804	− 0.3147	+ 0.8044	− 0.3960	+ 0.1730	− 0.0982	+ 0.6966	+ 0.4832
1788	+ 0.1129	+ 0.5214	− 0.0935	− 0.3108	+ 1.0390	− 0.2942	+ 0.1651	− 0.1100	+ 0.2300	+ 0.7999
1789	− 0.4437	+ 0.5640	− 0.1061	− 0.3065	+ 0.9759	− 0.1802	+ 0.1567	− 0.1216	− 0.2923	+ 0.8308
1790	− 0.8835	+ 0.5820	− 0.1179	− 0.3018	+ 0.6502	− 0.0579	+ 0.1474	− 0.1331	− 0.7212	+ 0.6066
1791	− 1.1018	+ 0.5740	− 0.1291	− 0.2966	+ 0.1616	+ 0.0664	+ 0.1371	− 0.1443	− 0.9530	+ 0.2208
1792	− 1.0535	+ 0.5396	− 0.1395	− 0.2910	− 0.3693	+ 0.1877	+ 0.1260	− 0.1554	− 0.9444	− 0.2110
1793	− 0.7523	+ 0.4790	− 0.1490	− 0.2850	− 0.8110	+ 0.3003	+ 0.1140	− 0.1661	− 0.7073	− 0.5628
1794	− 0.2675	+ 0.3946	− 0.1576	− 0.2786	− 1.0507	+ 0.3978	+ 0.1014	− 0.1767	− 0.3091	− 0.7282
1795	+ 0.2842	+ 0.2897	− 0.1651	− 0.2718	− 1.0190	+ 0.4750	+ 0.0881	− 0.1870	+ 0.1370	− 0.6429
1796	+ 0.7561	+ 0.1679	− 0.1716	− 0.2646	− 0.7043	+ 0.5277	+ 0.0743	− 0.1971	+ 0.4878	− 0.2944
1797	+ 1.0018	+ 0.0401	− 0.1770	− 0.2571	− 0.1806	+ 0.5511	+ 0.0599	− 0.2069	+ 0.6078	+ 0.2235
1798	+ 0.9337	− 0.0916	− 0.1813	− 0.2492	+ 0.3992	+ 0.5452	+ 0.0452	− 0.2164	+ 0.4116	+ 0.7732
1799	+ 0.5711	− 0.2182	− 0.1843	− 0.2409	+ 0.8536	+ 0.5098	+ 0.0302	− 0.2256	− 0.0723	+ 1.1680
1800	+ 0.0345	− 0.3332	− 0.1862	− 0.2323	+ 1.0487	+ 0.4470	+ 0.0150	− 0.2345	− 0.7172	+ 1.2762
1801	− 0.5144	− 0.4305	− 0.1869	− 0.2234	+ 0.9447	+ 0.3615	− 0.0004	− 0.2430	− 1.3552	+ 1.0628
1802	− 0.9272	− 0.5058	− 0.1864	− 0.2141	+ 0.5915	+ 0.2571	− 0.0157	− 0.2512	− 1.8335	+ 0.5817
1803	− 1.1108	− 0.5563	− 0.1844	− 0.2047	+ 0.0684	+ 0.1404	− 0.0308	− 0.2590	− 2.0562	− 0.0610
1804	− 1.0261	− 0.5804	− 0.1817	− 0.1948	− 0.4384	+ 0.0171	− 0.0458	− 0.2664	− 1.9830	− 0.7385
1805	− 0.5942	− 0.5776	− 0.1777	− 0.1846	− 0.8578	− 0.1077	− 0.0606	− 0.2735	− 1.6841	− 1.2996

TABLE II.—*Continued.*

YEAR.	RECTANGULAR CO-ORDINATES OF THE FOUR GREAT PLANETS, THE SUN'S CENTRE BEING THE ORIGIN AND ITS RADIUS THE UNIT OF MEASURE. EQUINOX, 1850.								SUM OF THE COMPONENTS OF X AND Y.	
	$M^{iv}\ X^{iv}$	$M^{v}\ X^{v}$	$M^{vi}\ X^{vi}$	$M^{vii}\ X^{vii}$	$M^{iv}\ Y^{iv}$	$M^{v}\ Y^{v}$	$M^{vi}\ Y^{vi}$	$M^{vii}\ Y^{vii}$	X′	Y′
1806	− 0.1923	− 0.5506	− 0.1725	− 0.1742	− 1.0633	− 0.2263	− 0.0749	− 0.2802	− 1.0696	− 1.6447
1807	+ 0.3576	− 0.4981	− 0.1662	− 0.1636	− 0.9914	− 0.3362	− 0.0888	− 0.2865	− 0.4703	− 1.7029
1808	+ 0.8061	− 0.4259	− 0.1588	− 0.1528	− 0.6419	− 0.4321	− 0.1020	− 0.2924	+ 0.0686	− 1.4684
1809	+ 1.0125	− 0.3363	− 0.1504	− 0.1426	− 0.0901	− 0.5107	− 0.1147	− 0.2979	+ 0.8883	− 1.0134
1810	+ 0.8995	− 0.2332	− 0.1412	− 0.1303	+ 0.4726	− 0.5691	− 0.1266	− 0.3030	+ 0.3948	− 0.5251
1811	+ 0.5039	− 0.1208	− 0.1310	− 0.1188	+ 0.8979	− 0.6053	− 0.1378	− 0.3076	+ 0.1833	− 0.1528
1812	− 0.0441	− 0.0036	− 0.1202	− 0.1072	+ 1.0518	− 0.6181	− 0.1481	− 0.3118	− 0.2751	− 0.0262
1813	− 0.5810	+ 0.1137	− 0.1086	− 0.0955	+ 0.9096	− 0.6068	− 0.1576	− 0.3156	− 0.6714	− 0.1704
1814	− 0.9677	+ 0.2268	− 0.0964	− 0.0836	+ 0.5287	− 0.5719	− 0.1660	− 0.3189	− 0.9209	− 0.5281
1815	− 1.1153	+ 0.3304	− 0.0835	− 0.0715	+ 0.0136	− 0.5147	− 0.1735	− 0.3218	− 0.9899	− 0.9964
1816	− 0.9940	+ 0.4210	− 0.0702	− 0.0594	− 0.5046	− 0.4378	− 0.1800	− 0.3242	− 0.7026	− 1.4461
1817	− 0.6334	+ 0.4946	− 0 0564	− 0.0471	− 0.9001	− 0.3421	− 0.1854	− 0.3261	− 0.2428	− 1.7537
1818	− 0.1167	+ 0.5473	− 0.0424	− 0.0348	− 1.0712	− 0.2331	− 0.1898	− 0.3276	+ 0.3534	− 1.8217
1819	+ 0.4287	+ 0.5770	− 0.0281	− 0.0224	− 0.9591	− 0.1142	− 0.1931	− 0.3286	+ 0.9552	− 1.5950
1820	+ 0.8516	+ 0.5810	− 0.0138	− 0.0100	− 0.5755	+ 0.0098	− 0.1954	− 0.3291	+ 1.4088	− 1.0002
1821	+ 1.0155	+ 0.5587	+ 0.0008	+ 0.0024	− 0.0186	+ 0.1333	− 0.1965	− 0.3292	+ 1.5774	− 0.4110
1822	+ 0.8596	+ 0.5097	+ 0.0152	+ 0.0147	+ 0.5444	+ 0.2505	− 0.1966	− 0.3288	+ 1.3992	+ 0.2609
1823	+ 0.4335	+ 0.4349	+ 0.0294	+ 0.0271	+ 0.9368	+ 0.3555	− 0.1956	− 0.3279	+ 0.9249	+ 0.7685
1824	− 0.1227	+ 0.3397	+ 0.0435	+ 0.0394	+ 1.0495	+ 0.4427	− 0.1936	− 0.3266	+ 0.2999	+ 0.9720
1825	− 0.6459	+ 0.2254	+ 0.0578	+ 0.0516	+ 0.8691	+ 0.5068	− 0.1906	− 0.3248	− 0.3111	+ 0.8605
1826	− 1.0037	+ 0.0996	+ 0.0717	+ 0.0639	+ 0.4624	+ 0.5438	− 0.1865	− 0.3225	− 0.7685	+ 0.4972
1827	− 1.1143	− 0.0318	+ 0.0851	+ 0.0759	− 0.0610	+ 0.5516	− 0.1815	− 0.3197	− 0.9851	− 0.0100
1828	− 0.9570	− 0.1600	+ 0.0980	+ 0.0879	− 0.5693	+ 0.5299	− 0.1755	− 0.3166	− 0.9811	− 0.5315

1829	− 0.5635	− 0.2827	+ 0.1104	+ 0.0998	− 0.9694	+ 0.4787	− 0.1685	− 0.3129	− 0.0410	− 0.9421
1830	− 0.0100	− 0.3888	+ 0.1223	+ 0.1116	− 1.0781	+ 0.4029	− 0.1608	− 0.3088	− 0.1949	− 1.1898
1831	+ 0.4978	− 0.4746	+ 0.1335	+ 0.1231	− 0.9212	+ 0.3064	− 0.1522	− 0.3043	+ 0.2798	− 1.0718
1832	+ 0.8918	− 0.5366	+ 0.1441	+ 0.1345	− 0.5063	+ 0.1948	− 0.1429	− 0.2993	+ 0.6338	− 0.7537
1833	+ 1.0132	− 0.5740	+ 0.1539	+ 0.1457	+ 0.0629	+ 0.0737	− 0.1328	− 0.2939	+ 0.7388	− 0.2901
1834	+ 0.8145	− 0.5822	+ 0.1630	+ 0.1567	+ 0.6119	− 0.0506	− 0.1221	− 0.2881	+ 0.5520	+ 0.1511
1835	+ 0.3614	− 0.5655	+ 0.1713	+ 0.1674	+ 0.9700	− 0.1727	− 0.1105	− 0.2818	+ 0.1346	+ 0.4050
1836	− 0.2001	− 0.5243	+ 0.1788	+ 0.1780	+ 1.0410	− 0.2876	− 0.0989	− 0.2751	− 0.3676	+ 0.3794
1837	− 0.7073	− 0.4611	+ 0.1849	+ 0.1882	+ 0.8247	− 0.3903	− 0.0865	− 0.2681	− 0.7953	+ 0.0798
1838	− 1.0347	− 0.3789	+ 0.1910	+ 0.1982	+ 0.3941	− 0.4772	− 0.0737	− 0.2607	− 1.0244	− 0.4175
1839	− 1.1084	− 0.2816	+ 0.1957	+ 0.2079	− 0.1345	− 0.5451	− 0.0605	− 0.2529	− 0.9864	− 0.9930
1840	− 0.9141	− 0.1727	+ 0.1994	+ 0.2173	− 0.6302	− 0.5918	− 0.0470	− 0.2447	− 0.6701	− 1.5137
1841	− 0.5017	− 0.0569	+ 0.2022	+ 0.2264	− 0.9734	− 0.6153	− 0.0330	− 0.2362	− 0.1300	− 1.8579
1842	+ 0.0370	+ 0.0604	+ 0.2040	+ 0.2352	− 1.0693	− 0.6149	− 0.0190	− 0.2273	+ 0.5366	− 1.9305
1843	+ 0.5638	+ 0.1761	+ 0.2047	+ 0.2436	− 0.8782	− 0.5907	− 0.0050	− 0.2180	+ 1.1882	− 1.6919
1844	+ 0.9278	+ 0.2847	+ 0.2045	+ 0.2517	− 0.4336	− 0.5455	+ 0.0085	− 0.2086	+ 1.6687	− 1.1792
1845	+ 1.0046	+ 0.3817	+ 0.2033	+ 0.2594	+ 0.1439	− 0.4748	+ 0.0225	− 0.1987	+ 1.8490	− 0.5071
1846	+ 0.7643	+ 0.4636	+ 0.2011	+ 0.2667	+ 0.6758	− 0.3872	+ 0.0364	− 0.1886	+ 1.6957	+ 0.1364
1847	+ 0.2865	+ 0.5262	+ 0.1978	+ 0.2736	+ 0.9979	− 0.2839	+ 0.0500	− 0.1782	+ 1.2841	+ 0.5858
1848	− 0.2765	+ 0.5666	+ 0.1936	+ 0.2801	+ 1.0270	− 0.1691	+ 0.0633	− 0.1675	+ 0.7638	+ 0.7537
1849	− 0.7656	+ 0.5823	+ 0.1884	+ 0.2863	+ 0.7759	− 0.0468	+ 0.0764	− 0.1566	+ 0.2914	+ 0.6489
1850	− 1.0608	+ 0.5721	+ 0.1823	+ 0.2920	+ 0.3247	+ 0.0777	+ 0.0891	− 0.1455	− 0.0144	+ 0.3460
1851	− 1.0975	+ 0.5351	+ 0.1752	+ 0.2973	− 0.2074	+ 0.1985	+ 0.1014	− 0.1341	− 0.0899	− 0.0416
1852	− 0.8704	+ 0.4723	+ 0.1674	+ 0.3021	− 0.6899	+ 0.3098	+ 0.1131	− 0.1226	+ 0.0714	− 0.3896
1853	− 0.4322	+ 0.3857	+ 0.1586	+ 0.3065	− 1.0027	+ 0.4059	+ 0.1243	− 0.1109	+ 0.4186	− 0.5834
1854	+ 0.1139	+ 0.2792	+ 0.1491	+ 0.3104	− 1.0600	+ 0.4810	+ 0.1348	− 0.0990	+ 0.8526	− 0.5432
1855	+ 0.6270	+ 0.1564	+ 0.1388	+ 0.3139	− 0.8301	+ 0.5310	+ 0.1446	− 0.0870	+ 1.2561	− 0.2415
1856	+ 0.9564	+ 0.0280	+ 0.1278	+ 0.3169	− 0.3586	+ 0.5518	+ 0.1536	− 0.0748	+ 1.4291	+ 0.2720
1857	+ 0.9896	− 0.1033	+ 0 1160	+ 0.3194	+ 0.2242	+ 0.5431	+ 0.1618	− 0.0625	+ 1.3217	+ 0.8666
1858	+ 0.7098	− 0.2295	+ 0.1037	+ 0.3215	+ 0.7354	+ 0.5052	+ 0.1693	− 0.0502	+ 0.9055	+ 1.3597
1859	+ 0.2100	− 0.3403	+ 0.0908	+ 0.3231	+ 1.0203	+ 0.4422	+ 0.1758	− 0.0376	+ 0.2836	+ 1.6005
1860	− 0.3517	− 0.4384	+ 0.0775	+ 0.3243	+ 1.0081	+ 0.3524	+ 0.1814	− 0.0251	− 0.3884	+ 1.5168
1861	− 0.8197	− 0.5118	+ 0.0636	+ 0.3248	+ 0.7231	+ 0.2468	+ 0.1860	− 0.0126	− 0.9431	+ 1.1433

TABLE II.—*Continued.*

YEAR.	RECTANGULAR CO-ORDINATES OF THE FOUR GREAT PLANETS, THE SUN'S CENTRE BEING THE ORIGIN AND ITS RADIUS THE UNIT OF MEASURE. EQUINOX, 1850.								SUM OF THE COMPONENTS OF X AND Y.	
	$M^{iv}\ X^{iv}$	$M^{v}\ X^{v}$	$M^{vi}\ X^{vi}$	$M^{vii}\ X^{vii}$	$M^{iv}\ Y^{iv}$	$M^{v}\ Y^{v}$	$M^{vi}\ Y^{vi}$	$M^{vii}\ Y^{vii}$	X′	Y′
1862	− 1.0820	− 0.5596	+ 0.0496	+ 0.3250	+ 0.2584	+ 0.1292	+ 0.1895	− 0.0001	− 1.2670	+ 0.5720
1863	− 1.0813	− 0.5813	+ 0.0351	+ 0.3248	− 0.2793	+ 0.0054	+ 0.1920	+ 0.0124	− 1.3127	− 0.0695
1864	− 0.8205	− 0.5762	+ 0.0207	+ 0.3239	− 0.7458	− 0.1181	+ 0.1934	+ 0.0250	− 1.0521	− 0.6455
1865	− 0.3606	− 0.5458	+ 0.0061	+ 0.3226	− 1.0277	− 0.2371	+ 0.1938	+ 0.0375	− 0.5777	− 1.0385
1866	+ 0.1900	− 0.4921	− 0.0083	+ 0.3209	− 1.0452	− 0.3459	+ 0.1930	+ 0.0499	+ 0.0105	− 1.1482
1867	+ 0.6871	− 0.4181	− 0.0233	+ 0.3187	− 0.7767	− 0.4404	+ 0.1910	+ 0.0623	+ 0.5644	− 0.9638
1868	+ 0.9803	− 0.3268	− 0.0380	+ 0.3160	− 0.2805	− 0.5173	+ 0.1881	+ 0.0745	+ 0.9315	− 0.5352
1869	+ 0.9686	− 0.2227	− 0.0524	+ 0.3126	+ 0.3032	− 0.5736	+ 0.1840	+ 0.0866	+ 1.0061	+ 0.0002
1870	+ 0.6509	− 0.1097	− 0.0664	+ 0.3091	+ 0.7906	− 0.6076	+ 0.1788	+ 0.0987	+ 0.7839	+ 0.4605
1871	+ 0.1330	+ 0.0077	− 0.0801	+ 0.3050	+ 1.0361	− 0.6181	+ 0.1725	+ 0.1104	+ 0.3656	+ 0.7009
1872	− 0.4246	+ 0.1246	− 0.0932	+ 0.3005	+ 0.9884	− 0.6045	+ 0.1652	+ 0.1223	− 0.0927	+ 0.6664
1873	− 0.8698	+ 0.2372	− 0.1056	+ 0.2955	+ 0.6670	− 0.5674	+ 0.1569	+ 0.1337	− 0.4427	+ 0.3902
1874	− 1.0979	+ 0.3397	− 0.1177	+ 0.2900	+ 0.1808	− 0.5084	+ 0.1476	+ 0.1452	− 0.5859	− 0.0348
1875	− 1.0599	+ 0.4291	− 0.1289	+ 0.2842	− 0.3505	− 0.4288	+ 0.1373	+ 0.1561	− 0.4755	− 0.4859
1876	− 0.7667	+ 0.5008	− 0.1393	+ 0.2779	− 0.7976	− 0.3325	+ 0.1262	+ 0.1672	− 0.1273	− 0.8867
1877	− 0.2872	+ 0.5512	− 0.1488	+ 0.2711	− 1.0464	− 0.2223	+ 0.1142	+ 0.1776	+ 0.3863	− 0.9769
1878	+ 0.2648	+ 0.5786	− 0.1574	+ 0.2640	− 1.0283	− 0.1025	+ 0.1017	+ 0.1882	+ 0.9500	− 0.8358
1879	+ 0.7420	+ 0.5799	− 0.1650	+ 0.2564	− 0.7203	+ 0.0218	+ 0.0884	+ 0.1980	+ 1.4183	− 0.4126
1880	+ 0.9959	+ 0.5551	− 0.1715	+ 0.2485	− 0.2016	+ 0.1449	+ 0.0746	+ 0.2062	+ 1.6280	+ 0.2261
1881	+ 0.9416	+ 0.5037	− 0.1768	+ 0.2403	+ 0.3792	+ 0.2613	+ 0.0603	+ 0.2173	+ 1.5088	+ 0.9181
1882	+ 0.5881	+ 0.4275	− 0.1812	+ 0.2317	+ 0.8414	+ 0.3649	+ 0.0455	+ 0.2267	+ 1.0661	+ 1.4785
1883	+ 0.0546	+ 0.3292	− 0.1850	+ 0.2227	+ 1.0470	+ 0.4500	+ 0.0302	+ 0.2364	+ 0.4215	+ 1.7686
1884	− 0.4950	+ 0.2105	− 0.1880	+ 0.2134	+ 0.9588	+ 0.5129	+ 0.0178	+ 0.2440	− 0.2571	+ 1.7285

1886	— 1.1087	— 0.0446	— 0.1963	+ 0.1938	+ 0.1077	+ 0.5507	— 0.0133	+ 0.2598	— 1.1458	+ 0.9049
1888	— 0.7102	— 0.2944	— 0.1820	+ 0.1782	— 0.8454	+ 0.4787	— 0.0431	+ 0.2741	— 1.0194	— 0.1407
1890	+ 0.8388	— 0.4818	— 0.1726	+ 0.1514	— 0.9905	+ 0.3963	— 0.0725	+ 0.2868	— 0.1644	— 0.4990
1892	+ 1.0097	— 0.5749	— 0.1595	+ 0.1287	— 0.1218	+ 0.0616	— 0.0995	+ 0.2977	+ 0.4040	+ 0.1885
1894	+ 0.5218	— 0.5026	— 0.1418	+ 0.1053	+ 0.8894	— 0.1846	— 0.1247	+ 0.3068	— 0.0768	+ 0.8839
1896	— 0.5641	— 0.4516	— 0.1210	+ 0.0818	+ 0.9193	— 0.4019	— 0.1462	+ 0.3142	— 1.0554	+ 0.6954
1898	— 1.1147	— 0.2716	— 0.0973	+ 0.0560	+ 0.0334	— 0.5508	— 0.1642	+ 0.3196	— 1.4267	— 0.3620
1900	— 0.6500	— 0.0453	— 0.0707	+ 0.0318	— 0.8998	— 0.6164	— 0.1785	+ 0.3232	— 0.7342	— 1.3815
1902									— 0.5533	— 1.3970
1904									+ 1.1813	— 0.3589

TABLE III.

YEAR. JAN. 1.	LONG. OF PLANET VIII.	THE SUN'S CENTRE IS THE ORIGIN, AND ITS S. D. THE UNIT OF MEASURE.						POLAR CO-ORDINATES OF THE CENTRE OF GRAVITY OF THE SOLAR SYSTEM COMPUTED FOR FIVE GREAT PLANETS FOR 120 YEARS.		
		RECTANGULAR CO-ORDINATES OF PLANET VIII.		RECTANGULAR CO-ORDINATES FROM TABLE II.		SUM OF CO-ORDINATES.				
		X	Y	X′	Y′	X″	Y″	V	V′	R′
	deg.							deg. min.	deg. min.	
1783	223	−1.024	− .954	− .089	−1.515	−1.113	−2.470	65 10	245 10	2.652
1784	222	−1.040	− .936	+ .493	− .245	− .546	−2.181	75 56	255 56	2.249
1785	221	−1.057	− .918	+ .867	− .700	− .189	−1.618	83 19	263 19	1.630
1786	220	−1.072	− .899	+ .951	− .066	− .121	− .966	82 52	262 52	.973
1787	219	−1.088	− .880	+ .696	+ .483	− .391	− .397	45 24	225 24	.557
1788	218	−1.103	− .861	+ .230	+ .799	− .873	− .061	4 1	184 1	.876
1789	217	−1.118	− .842	− .292	+ .830	−1.410	− .011	28	180 28	1.440
1790	215	−1.146	− .803	− .721	+ .606	−1.867	− .196	6 8	186 8	1.838
1791	214	−1.160	− .782	− .953	+ .220	−2.113	− .562	14 54	194 54	2.186
1792	213	−1.174	− .762	− .944	− .211	−2.119	− .973	24 41	204 41	2.331
1793	212	−1.187	− .741	− .707	− .562	−1.894	−1.304	34 33	214 33	2.305
1794	211	−1.200	− .721	− .309	− .728	−1.509	−1.449	44 49	224 49	2.009
1795	210	−1.212	− .700	+ .137	− .642	−1.075	−1.342	51 19	231 19	1.719
1796	209	−1.224	− .678	+ .487	− .294	− .736	− .973	52 52	232 52	1.220
1797	208	−1.231	− .657	+ .607	+ .223	− .623	− .433	34 50	214 50	.767
1798	206	−1.258	− .613	+ .411	+ .773	− .846	+ .159	10 40	169 20	.861
1799	205	−1.269	− .591	− .072	+1.168	−1.341	+ .576	23 15	156 45	1.460
1800	204	−1.279	− .569	− .717	+1.276	−1.996	+ .706	19 29	160 31	2.109
1801	203	−1.289	− .547	−1.355	+1.062	−2.644	+ .515	11 2	168 58	2.705
1802	202	−1.298	− .524	−1.833	+ .581	−3.131	+ .057	1 3	178 57	3.121

1803	201	−1.307	−.501	−2.056	−.061	−3.363	−.562	9 30	189 30	8.400
1804	200	−1.315	−.478	−1.988	−.733	−3.296	−1.212	20 11	200 11	8.514
1805	199	−1.323	−.455	−1.534	−1.289	−2.857	−1.755	31 34	211 34	8.354
1806	197	−1.339	−.408	−1.089	−1.644	−2.429	−2.053	40 13	220 13	8.180
1807	196	−1.346	−.385	−.470	−1.702	−1.816	−2.088	48 59	228 59	2.768
1808	195	−1.349	−.362	+.063	−1.468	−1.290	−1.830	55 1	235 1	2.234
1809	194	−1.358	−.338	+.383	−1.013	−.975	−1.325	53 36	233 36	1.647
1810	193	−1.364	−.315	+.394	−.525	−.969	−.840	40 54	220 54	1.283
1811	192	−1.369	−.291	+.133	−.162	−1.236	−.443	19 45	199 45	1.314
1812	191	−1.374	−.267	−.275	−.026	−1.049	−.293	10 5	190 5	1.675
1813	190	−1.378	−.243	−.671	−.170	−2.050	−.413	11 24	191 24	2.092
1814	188	−1.381	−.194	−.920	−.528	−2.302	−.722	17 26	197 26	2.413
1815	187	−1.389	−.170	−.939	−.906	−2.339	−1.167	26 37	206 37	2.606
1816	186	−1.392	−.146	−.702	−1.446	−2.094	−1.592	37 15	217 15	2.633
1817	185	−1.395	−.122	−.242	−1.753	−1.638	−1.875	48 52	228 52	2.490
1818	184	−1.397	−.097	+.353	−1.821	−1.043	−1.919	61 28	241 28	2.184
1819	183	−1.398	−.073	+.955	−1.595	−.442	−1.668	75 8	255 8	1.726
1820	182	−1.399	−.048	+1.408	−1.090	+.009	−1.139	89 81	270 29	1.140
1821	181	−1.400	−.024	+1.577	−.411	+.177	−.435	67 50	292 10	.470
1822	179	−1.400	−.024	+1.399	+.260	−.001	+.285	89 50	90 10	.285
1823	178	−1.399	−.048	+.924	+.768	−.474	+.817	59 53	120 7	.944
1824	177	−1.398	−.073	+.299	+.972	−1.008	+1.045	43 35	136 25	1.516
1825	176	−1.397	−.097	−.311	+.860	−1.706	+.958	29 17	150 43	1.959
1826	175	−1.395	−.122	−.768	+.497	−2.164	+.619	15 58	164 2	2.251
1827	174	−1.392	−.146	−.965	+.010	−2.377	+.135	3 16	176 44	2.381
1828	173	−1.389	−.170	−.961	−.531	−2.320	−.360	8 50	188 50	2.350
1829	172	−1.381	−.194	−.641	−.943	−2.022	−.747	20 17	200 17	2.156
1830	170	−1.378	−.243	−.194	−1.199	−1.573	−.956	31 17	211 17	1.843
1831	169	−1.374	−.267	+.279	−1.071	−1.091	−.804	36 18	216 18	1.858
1832	168	−1.369	−.291	+.633	−.753	−.735	−.463	32 9	212 9	.868
1833	167	−1.364	−.315	+.738	−.290	−.625	+.024	2 13	177 48	.625
1834	166	−1.358	−.338	+.572	−.151	−.786	+.439	81 55	148 5	.926
1835	165	−1.349	−.362	+.134	+.405	−1.214	+.767	82 18	147 42	1.436

TABLE III.—*Continued.*

YEAR. JAN. 1.	LONG. OF PLANET VIII.	THE SUN'S CENTRE IS THE ORIGIN, AND ITS S. D. THE UNIT OF MEASURE.						POLAR CO-ORDINATES OF THE CENTRE OF GRAVITY OF THE SOLAR SYSTEM COMPUTED FOR FIVE GREAT PLANETS FOR 120 YEARS.		
		RECTANGULAR CO-ORDINATES OF PLANET VIII.		RECTANGULAR CO-ORDINATES FROM TABLE II.		SUM OF CO-ORDINATES.				
		X	Y	X′	Y′	X″	Y″	V	V′	R′
	deg							deg. min.	deg min.	
1836	164	− 1.346	+ .385	− .367	+ .379	− 1.713	+ .765	24 4	155 56	1.876
1837	163	− 1.339	+ .408	− .795	− .079	− 2.134	+ .488	12 53	167 7	2.190
1838	161	− 1.323	+ .455	− 1.024	− .417	− 2.348	+ .038	58	179 2	2.270
1839	160	− 1.315	+ .478	− .986	− .993	− 2.301	− .514	12 36	192 36	2.357
1840	159	− 1.307	+ .501	− .670	− 1.513	− 1.977	− 1.012	27 6	207 6	2.221
1841	158	− 1.298	+ .524	− .130	− 1.857	− 1.428	− 1.333	43 2	223 2	1.954
1842	157	− 1.289	+ .547	+ .536	− 1.930	− .752	− 1.383	60 53	240 53	1.546
1843	156	− 1.279	+ .569	+ 1.188	− 1.691	− .091	− 1.122	85 22	265 22	1.136
1844	155	− 1.269	+ .591	+ 1.668	− 1.179	+ .399	− .587	55 46	304 14	.710
1845	154	− 1.258	+ .613	+ 1.849	− .507	+ .591	+ .106	10 14	10 14	.600
1846	152	− 1.231	+ .657	+ 1.695	+ .136	+ .464	+ .793	59 39	59 39	.919
1847	151	− 1.224	+ .678	+ 1.284	+ .585	+ .059	+ 1.264	87 19	87 19	1.265
1848	150	− 1.212	+ .700	+ .763	+ .753	− .448	+ 1.453	72 51	107 9	1.521
1849	149	− 1.200	+ .721	+ .291	+ .648	− .908	+ 1.369	56 27	123 33	1.644
1850	148	− 1.187	+ .741	− .014	+ .846	− 1.201	+ 1.087	42 9	137 51	1.621
1851	147	− 1.174	+ .762	− .089	− .041	− 1.261	+ .720	29 41	150 19	1.456
1852	146	− 1.160	+ .782	+ .071	− .889	− 1.089	+ .893	19 51	160 9	1.158
1853	145	− 1.146	+ .803	+ .418	− .583	− .727	+ .219	16 47	163 13	.760
1854	143	− 1.118	+ .842	+ .852	− .543	− .265	+ .299	48 26	131 34	.400
1855	142	− 1.103	+ .861	+ 1.236	− .241	+ .132	+ .619	77 54	77 54	.688

1856	141	−1.088	+ .880	+1.429	+ .272	+ .341	+1.153	73 31	78 31	78 31	1.201
1857	140	−1.072	+ .899	+1.321	+ .866	+ .249	+1.766	81 58	81 58	81 58	1.784
1858	139	−1.057	+ .918	+ .905	+1.359	− .151	+2.278	86 12	93 48	93 48	2.283
1859	138	−1.040	+ .936	+ .283	+1.600	− .756	+2.537	73 24	106 36	106 36	2.648
1860	137	−1.024	+ .954	− .388	+1.516	−1.412	+2.471	60 15	119 45	119 45	2.850
1861	136	−1.007	+ .972	− .943	+1.143	−1.950	+2.115	47 20	132 40	132 40	2.878
1862	134	− .972	+1.007	−1.267	+ .572	−2.239	+1.579	35 12	144 48	144 48	2.739
1863	133	− .954	+1.024	−1.312	− .069	−2.267	+ .954	22 50	157 10	157 10	2.460
1864	132	− .936	+1.040	−1.052	− .645	−1.988	+ .394	11 15	168 45	168 45	2.022
1865	131	− .918	+1.057	− .577	−1.033	−1.496	+ .023	54	179 6	179 6	1.496
1866	130	− .899	+1.072	+ .010	−1.148	− .889	− .075	4 52	184 52	184 52	.891
1867	129	− .881	+1.088	+ .564	− .963	− .316	+ .124	21 51	158 36	158 36	.340
1868	128	− .861	+1.103	+ .931	− .535	+ .076	+ .568	82 57	82 57	82 57	.572
1869	127	− .842	+1.118	+1.006	+ .300	+ .163	+1.118	81 41	81 41	81 41	1.130
1870	125	− .803	+1.146	+ .783	+ .460	− .019	+1.607	89 19	90 41	90 41	1.607
1871	124	− .782	+1.160	+ .365	+ .700	− .417	+1.801	77 22	102 38	102 38	1.917
1872	123	− .762	+1.174	− .092	+ .666	− .855	+1.841	65 6	114 54	114 54	2.030
1873	122	− .741	+1.187	− .442	+ .390	−1.184	+1.577	53 6	126 54	126 54	1 972
1874	121	− .721	+1.200	− .585	− .034	−1.306	+1.165	41 43	138 17	138 17	1.751
1875	120	− .700	+1.212	− .475	− .485	−1.175	+ .726	31 43	148 17	148 17	1.392
1876	119	− .678	+1.224	− .127	− .836	− .805	+ .387	25 42	154 18	154 18	.894
1877	118	− .657	+1.231	+ .386	− .976	− .271	+ .254	43 9	136 51	136 51	.371
1878	116	− .613	+1.258	+ .950	− .835	+ .336	+ .422	51 28	51 28	51 28	.539
1879	115	− .591	+1.269	+1.413	− .412	+ .821	+ .856	46 11	46 11	46 11	1.187
1880	114	− .569	+1.279	+1.628	+ .226	+1.058	+1.505	54 53	54 53	54 53	1.840
1881	113	− .547	+1.289	+1.508	+ .918	+ .961	+2.207	66 28	66 28	66 28	2.408
1882	112	− .524	+1.298	+1.066	+1.478	+ .541	+2.776	78 58	78 58	78 58	2.829
1883	111	− .501	+1.307	+ .421	+1.736	− .080	+3.043	88 29	91 31	91 31	3.045
1884	110	− .478	+1.315	− .257	+1.728	− .735	+3.043	76 25	103 35	103 35	3.131
1886	107	− .408	+1.339	−1.145	+ .904	−1.554	+2.244	55 17	124 43	124 43	2.730
1888	105	− .362	+1.349	−1.013	− .140	−1.375	+1.208	40 38	139 22	139 22	1.813
1890	103	− .315	+1.364	− .164	− .489	− .479	+ .875	61 18	118 42	118 42	.998
1892	101	− .267	+1.374	+ .404	+ .138	+ .136	+1.513	84 50	84 50	84 50	1.519

TABLE III.—*Continued.*

YEAR. JAN. 1.	LONG. OF PLANET VIII.	THE SUN'S CENTRE IS THE ORIGIN, AND ITS S. D. THE UNIT OF MEASURE.						POLAR CO-ORDINATES OF THE CENTRE OF GRAVITY OF THE SOLAR SYSTEM COMPUTED FOR FIVE GREAT PLANETS FOR 120 YEARS.		
		RECTANGULAR CO-ORDINATES OF PLANET VIII.		RECTANGULAR CO-ORDINATES FROM TABLE II.		SUM OF CO-ORDINATES.				
		X	Y	X′	Y′	X″	Y″	V	V′	R′
	deg.							deg. min.	deg. min.	
1894	98	− .194	+ 1.381	− .076	+ .883	− .271	+ 2.265	83 10	96 50	2.281
1896	96	− .146	+ 1.392	− 1.055	+ .685	− 1.201	+ 2.078	59 58	120 2	2.401
1898	94	− .097	+ 1.397	− 1.426	− .362	− 1.524	+ 1.035	34 11	145 49	1.842
1900	92	− .048	+ 1.399	− .734	− 1.361	− .783	+ .037	2 45	177 15	.781
1902	89	+ .024	+ 1.400	+ .553	− 1.396	+ .577	+ .004	24	24	.573
1904	87	+ .073	+ 1.398	+ 1.312	− .358	+ 1.385	+ 1.089	37 34	37 34	1.704

TABLE IV.

YEAR.	POLAR CO-ORDINATES FOR FOUR GREAT PLANETS AND FIVE GREAT PLANETS.				WOLF'S MEAN NUMBER OF SUN SPOTS FOR JANUARY FIRST OF EACH YEAR.			THE YEARS OF SUN SPOT.	THE YEARS OF SUN SPOT.
	V	R	V′	R′	DECEMBER.	JANUARY.	SUM.	MAXIMA.	MINIMA.
	deg. min.		deg. min.						
1783	266 37	1.518	245 10	2.652	31.4	30.6	62.		
1784	291 38	1.339	255 56	2.249	14.1	12.3	26.		1784.7
1785	321 4	1.115	263 19	1.630	11.9	13.9	26.		
1786	356	.954	262 52	.973	46.3	49.6	96.		
1787	34 45	.848	225 24	.557	107.9	111.4	219.		
1788	73 57	.882	184 1	.876	137.8	140.6	278.	1788.1	
1789	109 23	.881	180 28	1.440	127.3	124.9	252.		
1790	139 56	.942	186 8	1.838	109.2	106.0	215.		
1791	166 57	.978	194 54	2.186	75.9	74.8	151.		
1792	192 36	.968	204 41	2.331	63.3	62.1	125.		
1793	218 31	.904	214 33	2.305	55.3	55.1	110.		
1794	247	.791	224 49	2.009	41.4	40.7	82.		
1795	282 2	.657	231 56	1.705	32.0	29.8	62.		
1796	328 28	.572	232 52	1.220	20.1	20.2	40.		
1797	20 11	.648	214 50	.767	9.5	8.8	19.		
1798	61 58	.876	169 20	.861	4.7	4.1	9.		1798.3
1799	98 32	1.170	156 45	1.460	7.3	7.8	15.		
1800	119 20	1.498	160 31	2.109	7.1	8.0	15.		
1801	141 54	1.723	168 58	2.705	24.3	25.2	50.		
1802	162 24	1.924	178 57	3.121	42.5	44.4	87.		
1803	181 42	2.057	189 30	3.409	64.2	65.6	130.		
1804	200 18	2.114	200 11	3.514	74.9	75.1	150.	1804.2	

TABLE IV.—*Continued.*

YEAR.	POLAR CO-ORDINATES FOR FOUR GREAT PLANETS AND FIVE GREAT PLANETS.				WOLF'S MEAN NUMBER OF SUN SPOTS FOR JANUARY FIRST OF EACH YEAR.			THE YEARS OF SUN SPOT.	THE YEARS OF SUN SPOT.
	V	R	V′	R′	DECEMBER.	JANUARY.	SUM.	MAXIMA.	MINIMA.
	deg. min.		deg. min.						
1805	218 29	2.088	210 41	3.440	61.9	59.6	122.		
1806	236 28	1.973	220 13	3.180	37.9	36.3	74.		
1807	254 34	1.767	228 59	2.768	20.3	18.9	39.		
1808	272 41	1.470	235 1	2.234	6.5	6.3	13.		
1809	290 43	1.083	233 36	1.647	7.2	6.8	14.		
1810	306 53	.658	220 54	1.288	0.4	0.1	0.		1810.6
1811	311 6	.203	199 45	1.314	0.0	0.0	0.		
1812	185 26	.276	190 5	1.675	2.9	2.7	5.		
1813	194 18	.693	191 24	2.092	7.8	8.4	16.		
1814	209 50	1.062	197 26	2.412	15.9	16.2	32.		
1815	226 40	1.370	206 37	2.605	20.3	22.7	43.		
1816	244 5	1.608	217 15	2.633	47.6	47.3	95.	1816.4	
1817	262 8	1.770	228 52	2.490	43.9	44.1	88.		
1818	280 59	1.856	241 28	2.184	34.8	33.8	68.		
1819	300 55	1.859	255 8	1.726	24.8	24.6	49.		
1820	322 16	1 781	270 29	1.140	22.7	21.2	44.		
1821	345 24	1.630	292 10	.470	10.2	8.9	19.		
1822	10 54	1.425	90 10	.285	5.8	6.1	12.		
1823	89 43	1.202	120 7	.944	1.2	0.6	2.		1823.3
1824	72 51	1.017	136 25	1.516	6.3	6.3	13.		
1825	109 53	.915	150 43	1.959	8.9	10.8	20.		
1826	147 6	.915	164 2	2.251	23.1	24.9	48.		

1827	180 37	.985	176 44	2.881	45.8	46.2	92.			
1828	209 43	1.073	188 50	2.350	58.9	61.2	120.			
1829	235 46	1.140	200 17	2.156	61.3	61.9	123.	1829.9		
1830	260 18	1.156	211 17	1.842	70.9	68.5	139.			
1831	284 38	1.107	216 18	1.358	61.4	60.1	122.			
1832	310 4	.971	212 9	.868	41.3	39.8	81.			
1833	338 7	.796	177 48	.625	13.5	12.0	26.			1833.9
1834	15 19	.572	148 5	.926	7.4	7.7	15.			
1835	71 37	.427	147 42	1.436	24.2	27.4	52.			
1836	134 6	.528	155 56	1.876	93.2	99.5	193.			
1837	174 16	.799	167 7	2.190	139.4	142.7	282.	1837.2		
1838	202 10	1.106	179 2	2.270	126.2	125.4	252.			
1839	225 12	1.400	192 36	2.357	82.2	79.5	162.			
1840	246 7	1.655	207 6	2.221	81.9	80.6	163.			
1841	266	1.862	223 2	1.954	49.6	48.7	98.			
1842	285 32	2.003	240 53	1.546	28.8	26.7	53.			
1843	305 5	2.067	265 22	1.136	18.7	18.0	36.			1843.5
1844	324 44	2.048	304 14	.710	11.7	11.9	24.			
1845	344 40	1.917	10 14	.600	28.3	29.9	58.			
1846	4 36	1.701	59 39	.919	46.9	49.0	96.			
1847	24 30	1.411	87 19	1.265	64.8	65.9	131.			
1848	44 37	1.073	107 9	1.521	123.0	128.2	251.	1848.1		
1849	65 49	.711	123 33	1.644	120.7	116.4	237.			
1850	92 23	.346	137 51	1.621	77.7	75.6	153.			
1851	204 50	.099	150 19	1.456	67.0	66.6	134.			
1852	280 23	.396	160 9	1.158	59.7	59.4	119.			
1853	305 40	.718	163 13	.760	44.5	44.4	89.			
1854	327 41	1.016	131 34	.400	30.1	28.2	58.			
1855	348 57	1.259	77 54	.633	15.5	14.1	30.			
1856	10 47	1.455	73 31	1.201	3.2	3.8	7.			1856.0
1857	33 52	1.593	81 58	1.784	9.2	10.4	20.			
1858	56 20	1.654	93 48	2.283	36.0	38.6	75.			
1859	79 57	1.625	106 36	2.648	75.5	78.9	154.			
1860	104 22	1.566	119 45	2.850	95.4	97.2	192.	1860.1		

TABLE IV.—*Continued.*

YEAR.	POLAR CO-ORDINATES FOR FOUR GREAT PLANETS AND FIVE GREAT PLANETS.				WOLF'S MEAN NUMBER OF SUN SPOTS FOR JANUARY FIRST OF EACH YEAR.			THE YEARS OF SUN SPOT.	THE YEARS OF SUN SPOT.
	V	R	V′	R′	DECEMBER.	JANUARY.	SUM.	MAXIMA.	MINIMA.
	deg. min.		deg. min.						
1861	129 31	1.482	132 40	2.878	90.6	88.1	179.		
1862	155 42	1.390	144 48	2.739	68.1	67.7	136.		
1863	183 2	1.315	157 10	2.460	55.3	51.9	107.		
1864	211 32	1.234	168 45	2.022	43.2	44.8	88.		
1865	240 48	1.184	179 6	1.496	41.3	39.1	80.		
1866	270 31	1.148	184 52	.891	24.2	22.8	47.		
1867	300 22	1.117	158 36	.340	6.8	5.9	13.		1867.2
1868	330 7	1.074	82 57	.572	17.1	19.3	36.		
1869	— 0	1.006	81 41	1.130	56.9	61.4	118.		
1870	30 26	.909	90 41	1.607	105.8	110.0	216.	1870.6	
1871	62 27	.790	102 38	1.917	135.4	132.3	268.		
1872	97 55	.673	114 54	2.090	98.0	98.9	197.		
1873	138 36	.590	126 54	1.972	92.1	87.8	180.		
1874	183 24	.587	138 17	1.751	52.0	51.8	104.		
1875	225 37	.680	148 17	1.392	32.7	29.8	63.		
1876	261 21	.846	154 18	.894	12.5	11.7	24.		
1877	291 34	1.050	136 51	.371	——	——	——		
1878	318 40	1.265	51 28	.589	——	——	——		1878.9
1879	345 45	1.472	46 11	1.187					
1880	7 35	1.642	54 53	1.840					
1881	31 19	1.766	66 28	2.406					
1882	54 12	1.823	78 58	2.829					

1883	76 33	1.813	91 31	8.045	
1884	98 26	1.747	108 35	8.131	
1886	141 42	1.460	124 43	2.790	
1888	187 54	1.023	189 32	1.813	
1890	251 26	.516	118 42	.996	
1892	18 55	.497	84 50	1.519	
1894	94 58	.887	96 50	2.281	
1896	147 —	1.258	120 2	2.401	
1898	194 14	1.472	145 49	1.843	
1900	241 40	1.547	177 15	.781	
1902	291 37	1.502	24	.573	
1904	344 43	1.360	87 34	1.704	

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